APPROPRIATE TECHNOLOGY: RESEARCH IN ALTERNATIVE AGRICULTURE SYSTEMS

HEARING

BEFORE THE

SUBCOMMITTEE ON NATURAL RESOURCES,
AGRICULTURE RESEARCH AND ENVIRONMENT

OF THE

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APPROPRIATE TECHNOLOGY: RESEARCH IN ALTERNATIVE AGRICULTURE SYSTEMS

THURSDAY, SEPTEMBER 30, 1982

Committee on Science and Technology, House of Representatives, Subcommittee on Natural Resources, Agriculture Research and Environment,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9:25 a.m., in room 2318, Rayburn House Office Building, Hon. James H. Scheuer (chairman of the subcommittee) presiding.

Present: Representatives Scheuer, Sensenbrenner, and Schneider.

Staff present: Dr. James C. Greene, science consultant, and Maryanne Bach, minority technical consultant.

Mr. **Scheuer**. This hearing of the Subcommittee on Natural Resources, Agricultural Research and Environment will come to order. Today we will continue to examine the needs for research in appropriate agricultural technology for the Third World and for the United States. The research would produce the kind of systems that would enable the small-scale farmer to improve his productivity, without the need for very costly, high technology capital inputs, without the need for expensive fertilizer, without the need for expensive irrigation, without the need for expensive and sometimes totally nonavailable energy inputs.

All of this is of critical importance because, by the end of the century, we are going to add another 2 to 2.5 billion to the world's population. Ninety percent of these people will live in developing world countries. Ninety percent of the increase in population will live in developing world countries on marginal lands that are ill suited for food production. In the Third World countries these marginal lands are far more extensive than are the fertile urban zones.

Moreover, developing a research strategy for the transformation of subfertile areas into agriculturally productive areas is difficult and challenging. In the past most of our research efforts centered on issues involving fertile land crop production. Therefore, our experience in producing appropriate agricultural technology for developing countries is limited.

This raises the issue as to whether or not an adequate technology program to assist these countries over the next decade or two can be developed. If past history is any guide, then our concerns are well founded because the history of our agricultural research and development programs is one of an abiding concentration with high technology answers, high energy and high capital inputs.

For more than a century the Western model of agricultural technology, powered by scientific advances and high technology inputs, has been dominant throughout the world, so it is no surprise that the newly developed or less developed countries have sought to follow this model, which is quite inappropriate to their needs, in their development plans. Therefore, while there have been a few success stories, the fact remains that over 1 billion people have not benefited from high technology oriented agricultural research. Tens of millions if not hundreds of millions around the world are starving and are malnourished, and the chances for future improvement in their plight are bleak indeed.

Because of the failure of the developed world to come up with agricultural and development modalities that are appropriate to less developed countries, many policymakers are beginning to question the wisdom of high technology transfers in agriculture from the industrialized countries of the West to the developing nations. The large-scale, capital-intensive technologies developed in Europe and North America, Australia, New Zealand, Canada, Japan, may be efficient but their introduction into poorer, less developed societies frequently does not lead to increases in food production.

Therefore, it is imperative for us to apply our research and development efforts into new types of agricultural technology and new forms of organizations which are better suited to local conditions and local needs in the developing world. On the one hand, we are concerned about the adequacy of our technology program; on the other hand, we are encouraged to note there are several projects underway to develop this needed appropriate technology.

Examples of these efforts include projects on drainage, irrigation, plant breeding, erosion control, and agricultural management techniques. In the area of research, several projects are underway to investigate ecologically sound farming practices, integrated pest management, and resource conserving aquaculture—that is, the farming of the sea—all of which can be applied in developing countries as well as in our own.

Today's hearings will examine the current status of research and development in these and other related areas. We will hear testimony from witnesses on the research needs in alternative agricultural technologies, or appropriate technology, or intermediate technology, however you wish to characterize it, for developing countries, and on the extent to which these techniques can also be applied to small-scale farmers in the United States.

Therefore, without further ado we will begin with our first witness, Dr. Nyle C. Brady, Senior Assistant Administrator of the Agency for International Development. Dr. Brady was our lead witness 2 weeks ago when we had a very interesting hearing on deforestation, and we were all very much impressed with and grateful for his testimony.

Dr. Brady, we very much look forward to hearing from you today. Your prepared testimony, of course, will be printed in full at the appropriate point in the record, so perhaps you might want to chat with us informally for 8 or 10 minutes and then I am sure we will have some questions for you. This is the penultimate day of our session before we wind up. This is our next to last day, so we may or may not have a great attendance here.

In any event, all of the members are very much interested in this series of hearings on agricultural research needs in the developing world and how the U.S. agricultural research and development fraternity can better organize and better design our agricultural research to better fit the needs not only of our own small-scale farmers, but for the farmers of the developing world. Dr. Brady, we are delighted to have you back, and the floor is now yours.

STATEMENT OF DR. NYLE C. BRADY, SENIOR ASSISTANT ADMINISTRATOR, AGENCY FOR INTERNATIONAL DEVELOPMENT

Dr. **Brady**. Thank you, Mr. Chairman. I appreciate this opportunity to testify today on behalf of the Agency for International Development. I also appreciate very much your dedication to the use of science and technology for the developing world, and your interest in what we are doing.

I think we all recognize, as you pointed out in your opening statement, that the primary cause of the difficulties that we find ourselves in is the fact that in some places in the world the population numbers pressuring and in some cases outstripping the capacity of people to produce food. We have to recognize that even though there are some things we can do right now to take care of the current situation, in the long run we must help these countries develop programs that will bring their population numbers somewhat more in balance with their capacity to produce food. The population-food issues are intertwined and they have to be approached at the same time.

Mr. **Scheuer**. Let me just interject and say that I totally agree with what you are saying. This is not a hearing on rational population policies in the Third World, but I agree with you that it is almost absurd to consider food needs without considering population trends.

I was the first chairman of a parliamentary committee on population and development problems in the world. The U.S. Congress set up the first committee on population and development. Now there are dozens and dozens of them in parliaments around the world. There was a conference of parliamentarians under the aegis of the United Nations in Sri Lanka in 1979, and they issued a unanimous report citing exactly the relationships that you cited, the irresistible, inevitable, ineluctable relationship between explosive population growth and the destruction of the viability of all of our development programs for food and housing, education, and above all, jobs.

At the present I do not want to get into an extended discourse, but you sort of triggered me and I come charging out of the firehouse like the old fire horse. At the present rate of population growth and at the present rate of unemployment and underemployment, by the year 2000 the developing world will have a need for an additional 650 to 700 million jobs over and above what they have now. Now that is more than the entire employed population of the Western world, of the developed world, of the industrialized world. It is inconceivable that there is any remote possibility that this is going to happen, so underemployment and unemployment are going to get worse, there is going to be less and less in the way of net disposable income in the developing world on a per capita basis to buy food, there is going to be more social disorientation of the kind that you have in Kenya where you have a rampant rate of infanticide, a rampant rate of child abandonment, a rampant phenomenon of teenage gangs wandering violently and heedlessly through urban communities, with all of the social destruction that that implies.

Therefore, I just want to tell you how much I agree with you on that and will look forward to your testimony. I might say that we have been joined by one of our most hardworking and diligent members, Congresswoman Claudine Schneider of Rhode Island. We are very happy that in the final agonies of this session, on this next-to-last day, that you saw fit to break into your schedule and join us.

Would you like to make any remarks?

Mrs. **Schneider**. I have no opening remarks now, thank you.

Mr. **Scheuer**. OK. Please proceed, Dr. Brady.

Dr. **Brady**. Thank you, Mr. Chairman.

As we look back over the past 15 years and more, we do recognize that there has been some progress made on the part of agriculturalists in trying to keep up with this increase in population, particularly in Latin America and in Asia. There has been a slight increase in the per capita food consumption in those countries. Even so, the sheer numbers of people and particularly the fact that you have about 40 percent of the population under 15 years of age, means that the absolute numbers to be fed will still be very high, even if the percent rate of increase in population goes down somewhat.

However, in Africa we recognize that this progress has simply not been made. The increase in food production, in the continent as a whole, particularly south of the Sahara, simply has not been able to keep up with the population numbers. The per capita food production in Africa has gone down in spite of the fact that much more food has been produced. We have not generated the technology and gotten that technology put to use on African farms, so that they actually are producing less today per capita than they were producing 10 years ago.

Mr. **Scheuer**. If I can footnote that, a generation ago I believe every nation in sub-Saharan Africa was a food exporting country. It was their major source of cash income. Today, if I am not mistaken, every single country in sub-Saharan Africa, with the possible exception of the Ivory Coast and maybe one or two others, is a food importing country. That is almost a direct, inevitable consequence of the kind of population growth you are talking about.

Dr. **Brady**. I certainly agree.

The experience of the last 20 years has suggested that, if you want to simplify what it takes to bring about greater food production, first you have to have some kind of technology that fits the situation in the countries where the food is going to be produced. Second, you have to have the environment in which the farmer works, not only the physical environment but the social and political environment such that it pays the farmer to adopt the technology. When you have those two combined, the alleged resistance of the farmers in the developing countries to accepting new technologies tends to disappear. They may not be able to read and write but they can figure, and if they can see that they make more money by adopting the new technology, they will do so. However, if the price that they can get for their produce goes down at harvest time because of government policies, the farmer will not adopt the new technology. He cannot afford to.

Therefore, we recognize that the environment in which the farmer is working has much to do with the adoption and/or the transfer of technology, even though it may be developed in the country. The United States has taken the leadership on both of these elements in terms of helping countries increase their capacity to generate technology that fits them, and in terms of helping those countries see how the environment that the farmer lives in has to be such that he can make money before he will accept the technology.

I have made reference in my paper to the situation in India. I think I could use other countries. In Indonesia, one in which I worked, the situation is almost the same. The development of human resources and institutions had to be started and then this became the environment in which the technology could be generated and made available.

I would also like to comment that at the present time the U.S. Agency for International Development places technology generation and transfer and institutional development very high on its priority list. Mr. Peter McPherson came into the Agency with experience in the technical assistance, technology generation and transfer area, and has shown that he learned something while a Peace Corps volunteer, and as he sat on the BIFAD and made recommendations as to how AID could use the technology, and he has helped us organize ourselves in such a way that we can give greater attention to it. I have identified in my paper some of the ways we are using to try to get this done.

I would like to make reference to the fact that as we have carried on these programs to generate and transfer technology, we have kept in mind the fact that the people we are trying to serve are most of all the poor people of these developing countries. From my own experience overseas for 8 years, I became convinced that one of the primary ways that we could help the poorest of the poor, the landless laborers, the poor people in the cities, was to see to it that they had a consistent supply of food at a reasonable price.

I have identified also in my paper some examples of how the U.S. Agency for International Development has provided the kinds of inputs that have helped these people increase their capacity to feed themselves.

I would be pleased to answer any questions that the chairman and other members of the committee may have.

[The prepared statement, plus AID policy paper of Dr. Brady follows:]

STATEMENT OF

Dr. Nyle C. Brady
Senior Assistant Administrator for
Science and Technology

AGENCY FOR INTERNATIONAL DEVELOPMENT

Before the
SUBCOMMITTEE ON NATURAL RESOURCES,
AGRICULTURAL RESEARCH AND ENVIRONMENT
COMMITTEE ON SCIENCE AND TECHNOLOGY

U. S. House of Representatives
September 30, 1982

INTRODUCTION

I appreciate the opportunity to testify here today. On behalf of the Agency for International Development, I thank the Subcommittee for an opportunity to share some thoughts regarding the transfer of agricultural technology to the less developed countries (LDCs) and research on improved technologies appropriate for farmers in LDCs.

As we view the world food situation in developing countries today we can be pleased or unhappy depending on our point of view. If we consider the fact that in spite of all the world-wide efforts of the past decade to increase food production, little increase in per capita food production has occurred in the developing countries, we should be unhappy. Further distressing is the fact that in some countries such as those in sub-Sahara Africa per capita food production has actually gone down over this period. Food production and consumption remains well below the FAO minimum nutrition standards of 2000-2100 calories per person a day in most of the LDCs.

On the bright side, if we consider the difference between what was predicted in the 1960's and what has actually occurred in food production, we should be pleased.

Remarkable progress has been made in the past 20 years in increasing food production in the developing countries. The farmers of these countries have proven false the pessimistic assessments of the 60's as to their capacity to feed their countrymen in the face of unprecedented increases in population numbers. Since 1950 these countries have doubled their food production, a remarkable feat considering the difficulties they have had to overcome.

MAJOR FACTORS RESPONSIBLE FOR SUCCESS

I am certain the Committee is aware that the accomplishments of LDC farmers was no accident. Had there been no improvement in the crop varieties and associated technologies which I witnessed personally in Asia, and Latin America in the 1950's and 1960's, the pessimists would have been correct. Widespread hunger and starvation would have resulted and political chaos would likely have followed.

Two general factors are responsible for the developing countries having increased their food production at a rate which has held off catastrophy. First, through research and field testing improved technologies which are appropriate to the developing countries and which have the capacity to produce more food. Second, the non-farm environment (price policies, input availabilities, marketing mechanisms, institutions, etc.) has not only encouraged the farmer to adopt the improved technologies but has permitted him to make money by doing so. Both these processes are essential and both depend upon science and technology and upon the transfer of that technology to the end user.

EXAMPLES OF AID CONTRIBUTION

I am sure the Committee is aware of the extent to which the U. S. Government and U. S. institutions have contributed to the remarkable progress in food production around the world. The U. S. Agency for International Development and its predecessor aid agencies are responsible for no small part of this success. For example, the technology base which has made it possible for India to remarkably increase its food grain production in the past 15 years can be traced at least in some degree to two U. S.-assisted activities. First, U. S.-assisted partnerships in the 1960s between U. S. land grant universities and fledgling Indian agricultural universities helped India develop perhaps the strongest agricultural, scientific and technical base among the developing countries.

The second U. S.-assisted activity which has helped India is our support for two international agricultural research institutes: The International Center for the Improvement of Maize and Wheat in Mexico and the International Rice Research Institute in the Philippines. These two centers went into partnership with their Indian counterparts to produce and test short statured, high-yielding cereal varieties which have revolutionized food production in parts of India.

Similar success stories can be told as to how improved technologies developed with AID assistance became the bases for national agricultural revolution. These technologies have been a major factor in helping Indonesia, Sri Lanka and the Philippines markedly increase their food production. AID's inputs have not only been supportive of research and technology development in these countries but in building institutions to generate new technology and to accelerate its adoption by farmers.

Regretably, progress that has characterized agricultural production in Asia and Latin America is yet to be felt in most of the African countries south of the Sahara. With population increases among the highest in the world, per capita food production in these countries has actually decreased in the last decade. The technology generation and transfer systems which have been the bases for much of the successes elsewhere must now be adapted to African social and economic conditions. AID is giving priority attention to this need.

CANCUN INITIATIVE TEAMS

At the North-South summit talks in Cancun, Mexico, the overriding importance of food production in the developing countries was obvious. President Reagan offered to send teams of American agricultural experts to the countries which requested them. President Reagan has assigned the responsibility for coordinating the organizing of these teams to AID Administrator Peter McPherson. One of the three principal tasks of these teams is to identify opportunities for the application of existing technologies and determine needs for strengthening the capacity of local research and technology transfer systems to develop, adapt and apply agricultural technology in the participating country. Presidential task forces, responding to LDC requests as a result of the Cancun initiative, have been to Peru and Thailand. Two more are scheduled for October and November -- Honduras and Liberia. In addition, a special Presidential Mission has recently returned from Egypt. Their report was discussed in favorable terms with President Mubarak and various Cabinet members.

CURRENT AID EMPHASIS ON TECHNOLOGY DEVELOPMENT AND TRANSFER

-AID has traditionally supported efforts to develop and transfer technology in the developing countries. This traditional focus has been strengthened in the past 18 months by four significant actions:

a) Mr. McPherson has clearly identified technology transfer and associated institution development as one of the Agency's primary goals.

b) An Agency agricultural policy paper has been approved which requires renewed efforts to identify, transfer and adapt appropriate technologies. (Copy attached).

c) A Senior Assistant Administrator has been designated to provide Agency-wide leadership for science and technology and to head a reorganized central Bureau for Science and Technology.

d) Definite steps have been taken to enhance the participation of U. S. universities in the technology development and transfer.

e) We are reevaluating the role of the private sector both in the developing countries and in the United States in improving the technology development and transfer process.

Reorganization of the centrally supported research and development programs under a new Bureau for Science and Technology and the establishment of Agency-wide Science and Technology Sector Councils is helping to more sharply focus AID's agricultural technology programs. These Councils, comprised of key technical staff from the regional and central bureaus, provide an orderly mechanism for advising the Agency on all technical matters. Currently, they are developing an agricultural strategy paper which will suggest ways of implemmenting the approved agricultural policies. They are also working with a team of selected outside experts and with the country Mission in identifying high-priority research areas which should be pursued.

We are exploring a number of new approaches to working with U. S. universities in order to increase the input of their best scientific expertise to our overseas program. These approaches include a memorandum of understanding that will establish the mutual intent of the university and AID to use an appropriate amount of science and technology expertise over an extended time period. Another approach is the establishment of a development corps, which will provide for a specified group of university staff to spend about one-third of their careers working directly with AID, principally in overseas Missions.

A third approach is a "joint enterprise approach" toward developing and implementing projects. Joint-enterprise projects will be divided into "modules of work" and universities will be asked to indicate their interest in each module. Once we have the expressions of interest, the universities will be asked to form joint enterprises and submit formal proposals. We can then select the most appropriate proposal.

Our increased attention to the role of private enterprise in development recognizes that market mechanisms play a major part in the creation, adaptation and dissemination of technologies. We intend to strengthen efforts in support of local firms in fields such as manufacture and assembly of small-scale machinery, delivery of technology packages to small producers, and provision of agro-business and information services. Efforts will also go toward facilitating increased collaborative arrangemnts between U. S. and developing country businesses.

AGRICULTURE TECHNOLOGY GENERATION AND TRANSFER

The immediate objectives of our agriculture technology generation and transfer program are to:

-- increase and secure food supplies in LDCs;

--improve the quality of food;

--encourage the more equitable distribution and consumption of food.

--expand on-farm and off-farm employment of rural people in productive activities.

Achievement of these objectives requires massive improvement in the efficiency and productivity of technologies now used on the farms of the developing countries. We must help increase the level of knowledge and applicable appropriate technologies available to small producers. We must also strengthen the institutional process of getting those technologies adopted in the LDCs. Research designed to develop and adapt scientific and technological knowledge is infused in our agricultural and rural development programs -- as both a specific research effort and as a component of a broader effort.

The Agency's effort to generate and transfer technology is done through programs of the Central Science and Technology Bureau or through those of the regional bureaus and individual Missions. The S&T Bureau provides support for attacking global or interregional problems as well as technical backstopping for country Mission programs. The regional bureaus and country Missions are supporting some projects specifically concerned with technology generation and transfer. More commonly, however, technology related components are included in multi-faceted projects aimed at achieving broad development goals.

CENTRALLY FUNDED RESEARCH, TECHNOLOGY TRANSFER AND INTRA-AGENCY COOPERATION

- In principal, we should like to see each country evolve scientific and technical self-sufficiency for its own agricultural growth and rural development. In reality, however, the resource requirements for effective research and technology transfer are beyond what individual developing countries can afford. Our objective is to help the countries develop the capabilities they can afford and to supplement their efforts through assistance through international centers and U. S. universities. We try to take advantage of the technical expertise of U. S. institutions to develop new knowledge and technology which can be tested and modified to suit developing country needs.

Most U. S. based knowledge and technology cannot be "transplanted" directly without substantial additional research. To attempt to do this additional research country-by-country would be overwhelmingly expensive. Therefore, we help finance research directly aimed at developing new knowledge and technology specifically applicable to conditions characteristic of developing countries generally. These research efforts are centrally funded and are the responsibility of either the regional bureaus or the Science and Technology Bureau.

The Agency has two major efforts to generate agricultural technology applicable to developing countries. First is our partial support for the worldwide network of International Agricultural Research Centers (IARCs) and, second, support for collaborative research support programs (CRSPs) carried out by U. S. research institutions and overseas cooperators. These are the most cost-effective means of focusing scientific know-how on critical bottlenecks to agricultural and rural development. The IARCs have been a decided success. The high yielding varieties developed at these centers are grown today on more than one-third of the total wheat and rice lands in the developing world. The increased yields from these modern wheat and rice varieties are estimated to be feeding approximately 300 million people and the economic value of these additional food supplies is calculated to be somewhere between $3.0 and $5.0 billion annually. While the CRSPs have a much shorter history, we are expecting similar results to be forthcoming from them in the not-too-distant future.

Examples of other AID-supported activities to adapt and transfer appropriate technologies to LDCs in cooperation with other U. S. Government agencies, U. S. universities, the IARCs and private contractors are:

Crop Production

Sorghum-millet: It has been found that traditional West African methods of preparing sorghum and millet for food eliminate unfavorable features, such as indigestibility by children. Scientists working on the Sorghum/Millet CRSP expect to adapt the traditional techniques to broad-scale utility and to reduce unfavorable nutritional effects.

Improved Varieties: Ten U. S. universities and the USDA supply improved varieties of seeds to over 100 LDCs to increase nutritional value and productivity of major food crops.

Seed Technology: Mississippi State University has assisted more than 40 countries build modern seed production industries and train some 600 seed scientists. Some 34 in-country training courses have been given. This has enabled the LDCs to take advantage of the improved varieties developed during the last 20 years. As a result of these activities, 28 seed industries have been established in LDCs and 25 others assisted om their development.

Improved Rice: The International Center for Tropical Agriculture (CIAT) has developed an improved line of rice with the Colombian Government which is being widely accepted in Latin America. It performs well under non-irrigated conditions and requires less fertilizer and pesticides.

Crop Protection

Integrated Pest Management (IPM) systems minimize the need for expensive petrochemical pesticides. An aspect of IPM that has received considerable attention in A.I.D. is that which involves the development and testing of resistant plant strains. The CRSP program and many of the IARCs have ongoing research in this specific area.

Genetic Resistance to thrips is being bred into cassava at CIAT. IITA, as a result of a program with FAO, in Sierra Leone, has released 3 new strains of sweet potatoes and 3 varieties of cassava with good resistance to disease and pests.

IPM is receiving special attention in Africa under the auspices of the AID-funded FAO/CILLS Integrated Pest Management Research Project. Additionally, A.I.D. sponsors the West African Regional Food Crop

Protection Project which has ongoing studies related to IPM. In Latin America and Asia, special training programs convinced local crop protection researchers of the importance of IPM. In most cases the training programs are held in cooperation with other bilateral aid agencies or multilateral donors such as the FAO. There is almost no private sector involvement in IPM in either developed or developing countries. The responsibility for progress in this important area has always fallen heavily on the shoulders of the public sector.

Biological Nitrogen Fixation

The biological nitrogen fixation program is helping develop practical ways to enable crops to capture atmospheric nitrogen in their roots as an alternative to expensive chemical fertilizer. This program is being implemented by USDA and various State Experiment Stations. To broaden the base further, A.I.D. has initiated collaborative research and training programs with 12 LDCs.

Fertilizer

The International Fertilizer Development Center (IFDC) has demonstrated that improvement in rice yields, nitrogen recovery, and income distribution can be achieved through deep placement of fertilizer nitrogen and/or surface application of coated products.

IFDC is providing technical assistance to specific countries to help them manufacture, store and distribute fertilizer supplies on time. For example, in Bangladesh, IFDC has helped increase operation efficiency from 40 to 70 percent.

Soil Conservation and Management

Soil erosion is a critical problem throughout the developing world. It hurts the small farmer and national economic stability. To create awareness and programming in this field, A.I.D. is collecting environmental data of the developing countries. It has initiated a worldwide technical assistance program for improved soil management that is being implemented by USDA, Soil Conservation Service. A.I.D. is also considering development of LDC land-resource models that can predict the impact of soil degradation on food production over a fifty-year period for different levels of farming technology.

North Carolina State University has demonstrated in Peru that soils in the humid tropics may be farmed on a sustained basis if proven soil and fertilizer practices are followed. Farm incomes can be raised from $350 to $2800 per year without increasing the area under cultivation

Postharvest Food Losses

In 1980, A.I.D. established the Postharvest Institute for Perishables (PIP) at the University of Idaho. PIP is helping to reduce the wastage of perishable crops in LDCs by providing short-term technical assistance focusing on problems with postharvest handling, packaging, marketing, etc., by investigating food conservation technologies appropriate for transfer to LDCs, by providing specialized training courses in the host countries and in the U. S., and by coordinating with other donor technical assistance groups. PIP also supplies technical data to LDCs where libraries and technical journals are scarce. This transfers useful information to the LDC along with the ability to make better decisions related to how best to reduce the postharvest losses of valuable perishable commodities.

Fisheries

A.I.D. has initiated a program to provide transfer of information and application of appropriate technolgy in marine and aquaculture fisheries to the LDCs. In this process the implementing agencies and institutions include the National Marine Fisheries Services, National Oceanic and Atmospheric Agency and Auburn and Rhode Island universities. In addition, A.I.D. has a CRSP Pond Dynamics (aquaculture) and Stock Assessment (marine), with Oregon State and Maryland universities, to develop new technologies and methodologies in collaboration with LDC institutions.

Rhode Island has set up an information service focusing on small-scale fisheries development which will respond to specific requests and provide publications.

Farming Systems

This year A.I.D. began a major new initiative in Farming Systems Research and Technical Assistance. Research with a farming systems focus can have various objectives ranging from increasing the body of knowledge about farming systems to solving specific agricultural problems with the aim of increasing the productivity of the farming system by generating new technologies appropriate to the farmers.

The International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) has developed a simple but effective soil/water management system for heavy black soils of India and Africa. This system has already been tried on farmers' fields and found successful.

-Water Management

An example of improved water management techniques combined with innovations in soil conservation science is found in south-central Java. In a new basin development project where three million people live, for centuries farmers have been robbed of rich top soil when heavy rain washes out traditional rice terraces. Through the simple innovation of tilting the floors of the terraces backward into the hill, excess water flows to a rear ditch and the top soil remains in place.

A water management project in Pakistan focused on inefficiencies of water use, on farmers' attitudes, and on means of improving water management. The findings have influenced water management planning and implementation not only in Pakistan but in India, Sri Lanka, Thailand and Egypt.

Agro Forestry

We have entered into a cooperative agreement with the International Council for Agroforestry (ICRAF) in Kenya to carry out field testing and training in agroforestry. ICRAF will train LDC scientists and development agents to identify constraints to increased agroforestry production.

Small Farm Machinery

We are evaluating the potential for small scale farm machinery in Southeast Asia. Small (5-10 hp) power tillers, mechanical weeders, reapers, threshers and planters are being evaluated and technical assistance is given in their manufacture by indigenous manufacturers. Our primary objective is to extend the use of these machines to make possible more intensive cropping systems.

RESEARCH AT THE INDIVIDUAL COUNTRY LEVEL

Under the broadest terms of research, the largest share of A.I.D.-funded research is undertaken as a component of bilateral country programs. This work helps countries solve farm problems identified among and by its small farmers. In some cases, a research project is carried out on a specific problem:

- A project in Niger is breeding improved varieties of millet, sorghum and cowpeas and developing better production practice for these crops to increase production on farms in Niger's semi-arid, low-water crop growing areas.

- A project in Guatemala is developing farm organization and management systems to achieve greater total productivity at lower per unit costs from small farms.

While directed at solving local problems identified by farmers, experience has shown that these projects will undoubtedly have broad applicability to farmers in other countries.

In other instances our research is an element in projects with broader objectives. Most commonly this is in the form of assistance to strengthen LDC institutional capabilities for research and related functions, such as extension and agricultural teaching. In other cases, research is done as part of a specific development project such as an increase in corn production. Specific examples of our support of the research and technology transfer process are:

- A project in Liberia is assisting the Ministry of Agriculture with reorganization and improvement of its research and extension systems.
- A project in Zambia is helping the government strengthen agricultural research and improve the effectiveness of the extension services' work with small farmers.
- A project in Tanzania is assisting establishment of a coordinated capability in basic, applied and adaptive research to serve the needs of small farms.
- A project in Thailand is helping improve agricultural productivity in developing and applying new and appropriate technology on small, less-fertile dryland farms in northeast Thailand.
- A project is being designed to help Egypt with arid land agriculture. Research in the project will seek appropriate technology for increasing agricultural production under low water, low energy conditions.
- A project for West and East Africa provides for research on crop production technologies and development of improved cereals (sorghum, millet, and corn) and food legumes (cowpeas and peanuts) for small farms in the semi-arid areas found in 25 sub-Saharan African countries.

As part of these programs we support research in a variety of ways:

- National research institutions, preferably integrated with extension and teaching, are created or strengthened.

- Agriculturalists are provided research training locally, in the U.S., or in a third country.
- U. S. scientists are working with local scientists and farmers in joint local research.

The problems that need to be solved are numerous and complex. With a limit to the resources at our disposal we cannot hope to attack them all. However, by concentrating our efforts on those problems which are particularly urgent, and the solution of which will have the greatest impact, and by working jointly with other government agencies, U. S. institution, international organizations and the LDCs, I believe we can develop effective, innovative answers to some of the most difficult agricultural problems.

A.I.D. Policy Paper

FOOD AND AGRICULTURAL DEVELOPMENT

U.S. Agency for International Development
Washington, D.C. 20523
May 1982

A.I.D. Policy Paper

Food and Agricultural Development

Bureau for Program and Policy Coordination
U.S. Agency for International Development
Washington, D.C. 20523

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PREFACE

At the request of the Administrator an inter-bureau Task Force, including IDCA and BIFAD representation, was established to review A.I.D. policy on food and agricultural development assistance, and to make recommendations based on experience in developing countries and A.I.D.

This statement constitutes the report of the Task Force. It sets forth the overall objectives and policy elements of A.I.D. food and agricultural assistance funded from Development Assistance, Economic Support Fund and PL 480 budgets. It provides the basis for development of an A.I.D. Strategy Paper on Food and Agricultural Development that will delineate a strategy for linking the resources A.I.D. can draw upon for accomplishing its policy objectives.

This statement will also form the basis for discussions with other USG agencies, leading to the formulation of a U.S. Policy Statement on Food and Agricultural Development Assistance that will include policy implications for U.S. participation in multilateral organizations that provide food and agricultural assistance.

This statement supplements the A.I.D. Agricultural Development Policy Paper of June 1978 by providing a focus on major elements of A.I.D. policy.

The fulfillment of this policy requires long-term commitment from the United States and other donor nations and from developing countries, as well as from the private and public sector institutions involved. With mutual commitment to the policy, significant accomplishments can be expected over the next twenty years. Hunger and suffering will not be eliminated, but a significant number of additional countries will have become self-reliant in food and able to assure food security for their populations.

"Increasing food production in developing countries is critically important—for some, literally a matter of life and death. It is also an indispensable basis for overall development. The United States has always made food and agriculture an important emphasis of its economic assistance programs. We have provided massive amounts of food to fight starvation, but we have also undertaken successful agricultural research, welcomed thousands of foreign students for instruction and training at our finest institutes, and helped make discoveries of the high-yielding varities of the Green Revolution available throughout the world."

Ronald Reagan, PRESIDENT

Remarks to the World Affairs
Council of Philadelphia,
October 15, 1981

Background

Food production and consumption prospects are seriously deteriorating in a number of low-income, food-deficit countries. The basic causes of continuing hunger and malnutrition in these countries are inadequate food availability and inability of the malnourished to purchase or otherwise acquire and consume the food they need.[1] While this chronic deficiency receives less attention than outright starvation, it has a far wider impact on human lives and productivity.

Real progress has been made toward food and agricultural self-reliance in a number of Asian and Latin American countries, but many other countries remain beset with serious and precarious problems. Millions in Asia, Latin America and the Near East are still impoverished and malnourished. A deepening food crisis with chronic famine conditions in some areas is developing in sub-Saharan Africa, where per capita food and agricultural production continue to decline in a majority of countries.

Future prospects are influenced by two major factors: population growth and income growth. About 90 percent of the almost two billion increase in world population projected for the year 2000 will occur in developing countries, many of which are unable to assure adequate food supplies even for their current populations. Continuing per capita income growth in the middle-income and advanced developing countries is expected to generate substantial increases in the demand for basic grains for direct human consumption and for livestock production. Unless the production of major staples and/or other agricultural commodities in developing countries improves significantly more than it did during the 1960–75 period, and unless the effective demand of low-income families is increased through broad-based growth, a deterioration in per capita food availability and consumption, especially in low-income countries, may occur.

This is a grim picture, but it is by no means hopeless. The experience of the last 30 years shows that carefully planned and administered economic assistance, when combined with the fundamental efforts that a government and its people must themselves undertake, can establish a dynamic, self-sustaining food and agricultural system. U.S. assistance in the form of scientific and management expertise, and food and financial aid, has made critical contributions to the creation of such systems in South Korea, Brazil and Taiwan and to emerging self-reliance in countries such as India, Thailand and the Philippines.[2]

Experience over the last three decades also shows that dynamic agricultural growth is in most countries a necessary though not sufficient condition for broadly-based overall economic growth that permits the conquest of hunger, malnutrition and sustained improvement in per capita living standards. Broadly-based and shared economic growth, along with the effective provision of voluntary family planning services, will also bring about a reduction in rapid population growth. The United States should continue sustained support of efforts by the entire donor and international community to help developing countries achieve these goals.

The President of the United States has recently highlighted the importance of developing country food and agricultural problems and the role the U.S. is prepared to play in helping countries resolve these problems.[3]

I. Objectives

The overall objective of United States bilateral economic assistance is to stimulate in developing countries broadly-based, self-sustaining economic growth that promotes international peace and stability and that assists people to conquer poverty, hunger, illness and ignorance (see Sections 101 and 531 of the Foreign Assistance Act).

The objectives of U.S. food and agricultural assistance are to enable countries to become self-reliant in food, assure food security to their populations and contribute to broadly-based economic growth.

These broad objectives entail two major sub-objectives, namely:

1. **Increased food availability**, through:

- increased agricultural production, with an emphasis on increasing and sustaining the productivity, incomes and market participation of small farmers, with special attention to food production;

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[1] Inadequate nutrient absorption linked to disease and poor sanitation is a significant auxiliary cause, especially among infants and children.

[2] Self-reliance in food is defined as the ability of a country to assure continuing food security to its population from a combination of domestic production and importation of food at commercial terms paid from foreign exchange earnings. Short-run food security implies the ability to maintain normal consumption levels in the face of an emergency food shortage. Long-run food security is defined as the ability of a country to assure a nutritionally adequate food supply to its population on a continuing basis. Several of the countries mentioned above have clearly not yet achieved long-run food security in terms of nutritional adequacy. See p. 7 for further discussion.

[3] Of particular relevance are the "Remarks of the President to the World Affairs Council of Philadelphia" October 15, 1981, and the President's Statement of October 24, 1981, at Andrews Air Force Base on his return from the "North-South" Summit Conference at Cancun, Mexico.

- greater economic efficiency in the marketing and distribution of agricultural and food production, exports and imports; and

2. Improved food consumption in rural and urban areas, through:

- expanded productive employment and incomes of men and women who at present lack the purchasing power to obtain adequate food;
- increased awareness and incorporation of sound nutritional principles in the design and implementation of production, marketing, health and education policies and programs, including improved access to, and utilization of, food for those at nutritional risk;
- effective direct distribution of food from domestic or external sources to those facing severe malnutrition and temporary food shortages (i.e., a short-run lack of food security).

A.I.D. will seek to concentrate assistance for food and agricultural development in countries that share these objectives and are committed to an appropriate policy framework as elaborated in the following section on "Elements of Policy."

In supporting the objective of food self-reliance, A.I.D. does not rigidly subscribe to the goal of food self-sufficiency. A.I.D. supports a balanced approach involving economically viable expansion of agricultural production, including production for export and importation of food and agricultural products where comparative advantage exists.[4] As in the case of domestic food production, the employment, consumption and nutritional implications of export expansion will also be considered.

II. Elements of Policy

A.I.D. will emphasize four major, inter-related elements to accomplish food and agricultural development objectives:

- improve country policies to remove constraints to food and agricultural production, marketing and consumption;
- develop human resources and institutional capabilities, especially to generate, adapt and apply improved science and technology for food and agricultural development, and conduct research on developing country food and agriculture problems;
- expand the role of developing country private sectors in agricultural and rural development, and the complementary role of the U.S. private sector in assisting this expansion; and
- employ all available assistance instruments in an integrated manner, including provision of PL 480 food aid in a way that contributes to the other three strategy elements as well as meeting food security and nutritional needs.

Each of these elements is intended to increase the effectiveness of U.S. economic assistance resources. While the mix of these elements will vary according to the differing needs and problems among countries, the achievement of lasting food security requires greater attention to each of them in most developing countries.

The United States has strong technical competence in identifying and solving problems in food and agriculture. Maximum utilization will be made of this competence. A.I.D., other elements of the U.S. Government, such as USDA, cooperating universities and private sector organizations are prepared to make a long-term commitment to help those countries prepared likewise to make the requisite policy and resource commitments.

A main thrust of the policy is on the development of a domestic human and institutional capacity that permits a country to develop and apply food and agricultural science and technology. This recognizes the location-specific requirements for the effective application of improved agricultural technology. However, the policy also requires a more vigorous effort by A.I.D. to support the identification, transfer and adaptation of existing appropriate technologies, as well as the carrying out of food and agricultural research and application of improved technologies through U.S., international, regional and national institutions. These recommendations recognize that the continuing advance of agricultural technology, while not sufficient in itself, is an essential prerequisite to sustained improvement in food and agricultural performance. The policy also envisions strengthening institutional capability in other critical areas such as the management of irrigation and credit systems.

In pursuing this policy, A.I.D. will encourage countries to promote participation in food and agricultural development by the large majority of rural producers and workers, men and women, through:

- broadened access to production incentives and resources, including land and water, as well as opportunity to take advantage of education and training and other productive services;

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[4] In determining a balanced approach between production for domestic consumption and export, a country will weigh the risks inherent in increased dependence on world agricultural markets. These risks can be reduced somewhat by diversified production for export.

- increased productivity, employment and incomes; and
- expanded involvement in making policy and program decisions, including those affecting the development and operation of institutions that affect their productivity and well-being.

The policy also includes an emphasis on effectively increasing the productivity, incomes and market participation of small producers. These producers comprise the great majority of rural economic units in most countries and are thus important for both increased food production and consumption.[5] Evidence indicates they tend to employ land and purchased inputs in an economically efficient manner relative to large farmers. Furthermore, the demand for goods and services by the bulk of small farmers and their families who participate in market sales and purchases may constitute an important stimulus to off-farm rural enterprise and the generation of employment opportunities for landless laborers and for families engaged primarily in subsistence agriculture.[6] Improvement of the employment opportunities of the landless and near-landless is a crucial requirement for improved food consumption in many countries.

A. Improved Country Policies

The success or failure of the development process in a country depends heavily on its policy framework and the determination of the country itself. External assistance, while helpful and particularly critical in low-income countries, is in no case sufficient to achieve national food and agricultural development objectives. Sound country policies are fundamental to agricultural growth and to the effectiveness of external economic assistance. An appropriate policy framework is one that:

1. relies largely on free markets, the provision of adequate production incentives and the provision of equitable access to resources so that the broad majority of farmers, rural private sector entrepreneurs and workers—both men and women—have productive opportunities for employment, saving and investment; and
2. gives sufficient priority to complementary public sector investments in rural infrastructure and institutions that interact effectively with rural populations and complement and encourage rather than compete with healthy private sector growth.

Incentives are affected by direct attempts by government to influence the prices of food or agricultural products and inputs, but in many countries macro-economic policies affecting exchange rates, interest and wage rates and tariffs and taxes have an even more powerful impact on incentives to produce, employ, consume, save and invest. Furthermore, a wide range of government-promulgated regulations and privileges affect equitable access to such resources and services as land, water, credit, extension and marketing facilities. That is, distorted policies have hampered agricultural growth and have hurt the poor by excluding them from access to productive resources and employment.

Essential public sector investments are generally those that yield substantial returns to the economy but are of such a nature that the private sector is not prepared to undertake them, especially in low-income countries (reasons include high cost, uncertain or low returns in the short run, and/or difficulty for an individual investor to capture the returns). These investments usually include such major physical infrastructure as road networks and gravity irrigation systems as well as institutions for agricultural research, training and extension and for basic education and health services and control of epidemic diseases. However, in some aspects of research and extension, health services or training, for example, there may be more scope for private sector involvement than is often acknowledged.

- As part of its development assistance programming, A.I.D. will critically examine country policies affecting food and agricultural development and will seek to concentrate assistance in those countries where an appropriate policy framework already exists or where there is commitment to improvement.
- A.I.D. will analyze the constraints to improved policies in countries where it provides

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[5] The definition of a "small producer" will vary from country to country and region to region within countries. Influencing factors include sectoral (agriculture or industry), sub-sectoral or commodity mix, soil quality in the case of agriculture, etc.

[6] Of particular interest to A.I.D. are those small producers whose marketable surplus can be increased. It is recommended that a paper be prepared to analyze the extent to which increased production by commercial and/or semi-commercial farmers in developing countries will also meet employment and food consumption objectives through increased employment on such farms and indirectly through stimulus to off-farm rural enterprise. Although available evidence confirms the relatively high economic efficiency of small farmers, the question is complex. An analytical paper might explore further this question as well. In his Philadelphia World-Affairs Council remarks, op. cit., President Reagan indicated that the focus of American food and agricultural development assistance will be on "raising the productivity of the small farmer, building the capacity to pursue agricultural research and stimulating productive enterprises that generate employment and purchasing power."

assistance and will engage in dialogue with countries on changes in policies intended to improve incentives and opportunities.

- Technical assistance and training to improve a country's policy analysis and planning capacity will also be provided.

As part of its concern for improving the quantity and quality of food consumption, A.I.D. will continue its efforts on how to integrate effectively the implications of nutritional problems and practices into the design, implementation and evaluation of projects and programs. This concern includes but goes far beyond specialized efforts to correct specific nutritional deficiencies (e.g., Vitamin A, iodine, iron). A concern for nutritional implications will be included in dialogue on agricultural policies and in the design of assistance for planning and policy analysis; agricultural research and extension; education and training; marketing and processing; and food aid and food security. It will also be included in the formulation of assistance for health services, potable water and sanitation.

The incorporation of nutritional considerations raises complex, multi-sectoral issues that will be addressed further in an A.I.D. Nutrition Policy Paper in preparation.

B. Development of Human Resources and Institutional Capacity

A major priority of A.I.D. policy is to assist countries to develop and/or strengthen private and public institutions dealing with the host of technical, administrative, economic and social problems constraining increased and more efficient food and agricultural production, marketing and consumption.

Effective institutions provide a country the self-sustaining capacity to solve critical development problems. Furthermore, they:

- enhance a country's ability to marshall its own human and financial resources for food and agricultural development;
- enable individuals to obtain access to the skills, resources and services needed to increase their productivity, incomes and well-being; and
- increase the absorptive capacity and effectiveness of external assistance, thereby fostering development that continues beyond the period during which assistance is provided.

The creation and strengthening of institutional capacity, including development of the human resources needed for effective institutions, often requires a long-term commitment and effort—e.g., ten years or more—from A.I.D., the host country, other donors and cooperating organizations (Universities, PVO's, etc.). Missions must provide a sufficiently long-term assessment of how A.I.D. and other resources will be utilized to improve institutional capacities crucial to food and agricultural development in the host country.

Effective public and/or private institutions are required in most phases of food and agricultural development, including planning and policy analysis; construction, maintenance and operation of rural infrastructure (e.g., irrigation systems and rural roads); delivery of inputs, credit and other services; storage, marketing and processing of farm products; and other areas such as local government and taxation, and resource conservation and management.

Particularly vital to the establishment of self-reliant, sustainable food and agricultural systems are national institutions that give a country the capacity (1) to generate and apply a continuing stream of innovations designed to increase agricultural productivity and incomes; and (2) to evaluate and adapt technologies transferred from developed countries and international institutions. Advances in food and agricultural science and technology have not only increased productivity but have also facilitated the substitution of less expensive and more abundant resources for more expensive and increasingly scarce resources.

While the economic returns to agricultural research have been extremely high, it does take time to develop and test new technologies and to strengthen the national and local institutions required to adapt and apply technologies to location-specific conditions. The need to develop new technologies and strengthen institutions is especially critical for the large areas of the developing world that will continue to be dependent upon rain-fed agriculture.

In view of these considerations, A.I.D. will continue to provide direct support for food and agricultural research, training and technical assistance by U.S. and regional institutions, and by the system of international agricultural research centers. Collaborative projects with these institutions will be coordinated closely with efforts to improve national systems; networks for sharing knowledge among these institutions will be strengthened.

There are important interrelationships between country policies and institutional development. Institutions develop, implement and monitor policies that profoundly affect food and agricultural development. At the same time, the process of institutional development and of science and technology transfer, generation and application should be guided by a sound economic policy environment which reflects market forces. If this does not happen, improved agricultural technology may not be adopted by farmers, or if adopted, it may be inappropriate to the broader economic environment. For example, in some countries distorted economic policies have made capital artifically cheap and labor artificially expensive, resulting in the introduction of excessively capital-intensive technology. By the same token, production incentives alone are not usually sufficient to yield sustained advances in agricultural production. A continuous stream of productivity increasing, cost-reducing farm technology is also required.

- A.I.D. will therefore give special emphasis, with a sufficiently long-term commitment, to helping countries develop the institutional capacity for food and agricultural planning and policy analysis; basic and adaptive research, education and training; and disseminating improved technology and related information in a cost-effective manner.
- Social scientists (e.g., economists, anthropologists, development planners and policy analysts) and physical and biological scientists and technicians from developing countries and the United States will work together to conduct applied research and to develop individual and institutional capabilities intended to increase the productivities and incomes of the broad majority of rural producers.
- U.S. universities will marshall their best talent to play a major role in implementing A.I.D. assistance for food and agricultural institutional development. Other U.S. government agencies, particularly USDA, agribusiness enterprises, cooperatives and private voluntary organizations will also play significant roles.
- Aspects of agricultural research to be considered will include: innovative research to increase the genetic capabilities of plants and animals that are used as food; research on existing and more profitable farming and marketing systems, including their social, employment, energy, ecological and nutritional implications (including multiple cropping and water management); field-testing involving farmers; research and control of debilitating human and animal diseases that constrain agricultural productivity; and regular feedback to researchers of farmer experience with improved technologies.

A.I.D. will also encourage:

- an expanded role where appropriate for private enterprise in the provision of agricultural research and the dissemination of improved technology as well as in the processing, preservation and marketing of agricultural commodities (see following section);
- research and other institutions that expand access by low-income, small producers to improved technology, productive resources and services;[7] and
- voluntary institutions that mobilize local efforts for agricultural and social development.

Local institutions, including farmer organizations and land tenure arrangements, can also be critical in assuring that the majority of farmers benefit from improved technology and infrastructure. Clarity of ownership and title is critical to stimulating increased capital investment (and therefore production) at the level of the individual farmer.

Consequently, A.I.D. will give favorable consideration to requests for assistance in the form of feasible projects and programs that:

- establish wider access to agricultural assets, including land, and in providing more secure tenure arrangements; and
- strengthen local participatory organizations of agricultural producers that help assure access by farmers to resources and services and, through farmer involvement, improve the efficiency of such activities as irrigation utilization and maintenance.

Adequate human resources development is essential if food and agricultural institutions are to be effective. This means adequate training for professional and technical staff and for farmers.

A.I.D. will support:

- in-country training of scientists, technicians, managers, extension agents, and also farmers and skilled workers in food and nutrition, and agricultural and rural development, with expansion as necessary, of in-country training facilities;
- external training, in the United States or third countries.

Important in these regards, is the special role of and concern for women, including their role as agricultural producers, workers, and family food providers. Greater efforts are therefore required to expand opportunities for women to serve as administrators, scientists, technicians, extension workers and other food and agricultural professionals. A.I.D. will provide support to promote the enhancement of the role of women through:

- research and analysis;
- planning and policy dialogue;

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[7] Section 103A of the Foreign Assistance Act requires that agricultural research carried out under the Act take account of the special needs of small farmers in setting research priorities, as well as support research on the various factors affecting small farmers, and emphasize field-testing and research dissemination.

- design and implementation of institutional and human resource development and other programs; and
- A.I.D. staff recruitment, training and placement.

C. Expanding the Role of Developing Country and U.S. Private Sectors

Private sector business enterprises, including farmers and manufacturing, trade and service firms, account for the bulk of food and agriculture-related economic activity in many developing countries. Non-profit private and voluntary organizations (PVO's) also make significant contributions to food and agricultural development in many countries, as do universities (some developing country universities are entirely private; i.e., non-government, and others are perceived as private or quasi-government, due to their largely autonomous nature, even where mandated and funded by government).

Given an appropriate policy environment and the complementary support of public sector institutions and physical infrastructure, the private sector can constitute a dynamic, efficient and innovative mainspring for food and agricultural development. Furthermore, most private sector rural enterprise in developing countries tends to be relatively small-scale and labor-intensive. It thus also has the potential for generating substantial employment and purchasing power.

Realization of the full potential of the private sector to contribute to food and agricultural development requires attention to:

- government policies and regulations that encourage rather than discourage the private sector;
- programs to overcome deficiencies in management and technical skills; and
- private sector access to market and technical information, credit, infrastructure, services and materials.

In some countries long-established public enterprises or para-statal organizations dominate agricultural marketing, processing, storage and/or distribution activities. These operations are often highly inefficient and tend to discourage food and agricultural production. Avenues for improvement include: (1) policy and management reforms that give public enterprises a greater market orientation and put them on a commercial basis; (2) encouraging greater competition from private enterprises in the same spheres; and/or (3) turning public enterprise management and/or assets over to the private sector.[8]

A.I.D. will:

- identify private and public sector institutions, such as banks, technical institutes, and trade and marketing associations, through which technical and financial assistance can be effectively provided to private enterprise;
- engage in dialogue with governments on changes in policies and other regulations to encourage and strengthen private sector development, including small and medium-scale enterprise; and
- where appropriate, help countries improve the efficiency of public and para-statal enterprise engaged in food and agricultural-related activities. This is a complex issue that will be addressed further in a separate paper.

A.I.D. also encourages utilization of the invaluable skills and resources of the American private sector—of agribusiness enterprises, other firms and consultants, universities, cooperatives and other farmer organizations, and private and voluntary organizations—to stimulate broadly-based food and agricultural development.[9]

- A major effort will be made to involve U.S. business firms in strengthening developing country private enterprise.
- A.I.D. will develop mechanisms and processes to facilitate the involvement of the U.S. private business community in food and agricultural development, including technical assistance and training as well as direct and joint investment.

Private and voluntary organizations (PVOs) have a number of potential strengths for assisting food and agricultural development. PVOs can be effective in developing local institutions that organize local energies to provide both development and social services and productive inputs. Compared with the public sector, they often provide flexible, low-cost approaches that take local attitudes and conditions into account. Through their U.S. networks, they have the further advantage of mobilizing private

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[8] Such enterprises were often initiated for arguably laudible motives, such as reducing sharp, seasonal fluctuations in farm prices. Performance of public enterprises in accomplishing such objectives has been spotty, however, and the cost has been high. Private sector alternatives, including increased on-farm storage capacity, need more attention.

[9] U.S. universities will be used principally in support of A.I.D. policy to develop and strengthen institutions and train people serving agricultural and rural development as set forth in section B above. Such universities may also be utilized to support and strengthen the role of the private sector, including such activities as training, technical assistance, and joint efforts with PVO's and other public or private institutions.

American resources and commitment for development.

- A.I.D. will encourage and seek to strengthen PVOs that are commited to sustained food and agricultural development consistent with A.I.D. policy, and that have indicated through performance or potential the ability to provide effective developmental assistance.

D. Providing Food Aid and Food Security.

Food security considerations have played an increasingly important role in international discussions of food and hunger. The concept of international food security implies assurance world-wide of regular and adequate basic food supplies.

In emergencies or dire food shortages, national food security requires adequate capacity to channel available food supplies to population groups experiencing severe food shortages so as to maintain normal consumption levels. In the longer term, the achievement of national food security requires a country to be self-reliant in food and agriculture, to be capable of assuring its population a continuing, nutritionally adequate food supply through increased domestic production, more efficient distribution, expanded purchasing power and international trade, and a healthier and better informed population.

While external assistance can help accomplish these objectives, the responsibility for food security, especially in the longer term, is fundamentally that of each country. In the short term, international food assistance—led by the United States as the world's largest food aid donor—plays a vital role in assuring food security.

The United States has agreed to back up its pledge of food aid under the International Food Aid Convention with a national grain reserve—4 million tons of U.S. Government-owned, privately-held wheat, of which 300,000 tons may be used for disaster relief in any one year regardless of U.S. domestic supply conditions.[10]

PL 480 food aid can be a valuable development resource for augmenting local production, enhancing short- and long-term food security and reducing malnutrition, providing it is made available under conditions that support rather than discourage domestic food and agricultural production. PL 480 food commodities can enhance food security through augmenting domestic food sales and distribution programs and may also be used to help build national food reserves. Local currency generated from these food sales provides financial resources to assist with development of food and agricultural institutions and infrastructure.

- A.I.D. seeks to improve the impact of both PL 480 commodities and local currency proceeds on food and agricultural development, including increasing their integration with other U.S. bilateral financial and technical assistance at both the policy and project levels. PL 480 resources should support A.I.D.'s strategic emphases to improve country policies, develop human and institutional capacity and enhance the role of the private sector in food and agricultural development.
- The negotiation of PL 480 agreements is an opportunity for discussion of these issues with country governments and for including broader policy issues such as agricultural pricing and overall policy toward the private sector. Policy dialogue on PL 480 must reach agreement on supplying and/or conditioning food aid in a way that avoids disincentives to increased food and agricultural production through food subsidies or lowered government priority to domestic production. A.I.D. will pursue such policy dialogue in the context of total U.S. assistance to the country.

PL 480 Title II programs not only directly alleviate hunger and malnutrition but also have the potential to support human resource development and self-help efforts that increase the employment and employability of the lowest income groups. A.I.D. will continue to give greater emphasis in the use of PL 480 Title II resources to programs that have been shown to have greater nutritional impact, such as maternal-child health combined with nutrition education programs, rather than school-feeding programs, and encourage PVOs to design and implement Title II programs so that governments and local communities eventually assume responsibility for them and/or replace them with programs that increase production and incomes.

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[10] Under the U.S. Wheat Reserve Act of 1981. The 300,000 tons are to be used through PL 480 Title II after existing Title II resources have been committed or exhausted. In addition, access by foreign buyers to U.S. grain reserves held for commercial purposes also helps to assure food security.
A related question is the extent to which it is feasible and desirable for a developing country to hold food reserves as opposed to financial reserves to meet short-term food security problems. This is a complex question that depends upon a range of factors, including the size of the country, its location relative to international sources of supply, the nature of its comparative advantage for domestic food production and production for export, the effectiveness of its import and export infrastructure, its access to the recently-established IMF Food Financing Facility and other factors. It is recommended that guidelines be prepared on this question, including on the appropriate role for A.I.D. assistance.

III. Programming Implications

United States assistance strategy at the country level requires multi-disciplinary analysis of the policy, socio-economic, institutional and private sector settings for food and agricultural development as well as a long-term commitment of the United States and host countries. These will vary according to the differing needs and problems of countries. The precise content of assistance will thus depend on the conclusions of this analysis. The modes of assistance will be a combination of technical, capital, commodity and food aid assistance.

Although the context of A.I.D.'s assistance may vary from country-to-country for the reasons indicated above, the need to utilize limited budget and staff resources as effectively as possible implies a focused country assistance strategy, concentrating on a limited number of core sectors and sub-sectors. Missions should think in terms of long-term efforts in a few priority areas that involve joint and collaborative efforts with host country public and/or private institutions at every stage: identification and design, implementation, monitoring and evaluation. This approach should also permit some freeing-up of USAID staff for the important but relatively neglected implementation stage. It should be recognized that long-term commitment does imply that a certain portion of A.I.D.'s portfolio will be "mortgaged" for periods of a decade or so. But this is "mortgaging" consciously undertaken because of its positive developmental impact.

Technical assistance in the form of training opportunities and technical advisors will comprise a major mode of A.I.D. support for food and agricultural development.

The main U.S. sources of technical expertise are A.I.D. staff, American universities, private sector firms and organizations (agribusiness, consultants and other firms, cooperatives, farmer and private voluntary organizations), the Department of Agriculture and other U.S. Government agencies. A.I.D. will also draw upon technical assistance from other developing countries as well as on the food and agriculture development experience of the U.N. Food and Agriculture Organization (FAO), World Food Council (WFC), International Fund for Agricultural Development (IFAD), World Food Program (WFP) and other donor agencies.

In the utilization of these technical assistance resources A.I.D. will:

- encourage and strengthen the capacities of the various sources of U.S. and developing country technical assistance to, in turn, strengthen the counterpart capacities of host countries to address and solve their own food and agricultural development problems;
- give greater emphasis and importance to the Agency's science and technology capabilities, including creation of a strong professional staff; and
- enhance the role of American university expertise, as provided for by Title XII of the Foreign Assistance Act, in the implementation of A.I.D. food and agricultural development policy.

A.I.D. will also provide, under appropriate conditions, capital assistance, food aid, agricultural or other enterprise credit and/or commodity assistance. Such assistance can be especially critical to the development efforts of low-income countries. Capital assistance in particular is often closely linked to policy and/or institutional improvement in a project—e.g., capital assistance to construct or rehabilitate physical structures of an irrigation system linked to technical assistance for improved water management. Similar linkages should improve the effectiveness and lasting impact of all forms of assistance—e.g., elimination of subsidies or converting to private sector distribution as part of fertilizer assistance; interest rate reform as part of assistance for agricultural credit.

Therefore, A.I.D. will provide capital, food, credit or commodity assistance only when:

- a need for such assistance exists and other sources of financing have first been explored, including co-financing arrangements between A.I.D., other donors and/or private sources; and
- such assistance is linked to proposed changes or effective performance in the areas of institutional development, technology transfer or development, and/or economic policy.

Country performance will be closely monitored and evaluated to determine whether such assistance should be continued.

For low-income countries with severe local resource constraints, A.I.D. will consider financing a share of recurrent costs of food and agricultural research, education, extension or related institutions during the project development phase (up to ten years under current A.I.D. procedures), providing that the policy and institutional frameworks assure effective utilization and the country is making maximum and/or increasing domestic resource mobilization efforts.

Mr. **Scheuer**. Mrs. Schneider.

Mrs. **Schneider**. In your testimony you were mentioning some of the causes of food shortages and the increasing population. I would be curious to know, did the AID programs do any kind of appropriate technology transfer, insofar as addressing the problems of increasing population?

Dr. **Brady**. Yes.

Mrs. **Schneider**. How was that done?

Dr. **Brady**. One of the major programs of the Agency and of the bureau that I happen to be responsible for is family planning. This is done by making information available to the governments and, if the governments agree, to families as well, with regard to family planning. A primary objective is to see to it that they know the technologies that are available to help them, that they understand some of the consequences of unchecked population growth, and that we try working with the government to make available whatever methods are available so that they can regulate their families.

We have found a situation where, particularly among the women, they are eager to space their children. They do not want to have another child next year. They want children, they love them, but they would just as soon wait 3 years before they have their next one. They are then eager for information as to what they can do.

Mrs. **Schneider**. Well, why do you consider that there is a continuing increase in population in these areas despite the fact that we are providing them with the information on family planning?

Dr. **Brady**. Well, as is the case for the transfer of any kind of technology, it does take time. In Indonesia, the Philippines, Thailand, in India, already the percentage increase is beginning to go down, so some progress is being made. We do recognize, however, that when it comes to family planning, this is first and foremost an individual, personal decision, a family decision. It is also a decision of the Government in terms of the resources that they are going to put into this. We work with the Government so that it begins to put its own resources into these kinds of programs, and it simply takes time.

We moved forward later in Africa than we did in Asia because the population numbers were so much greater in Asia, even with the reduced rate of increase. However, now we see the situation worsening in Africa and we are working as fast as we can, in consonance with the governments and the families. We have to recognize that there are some social attitudes toward families, toward children, and in some societies, particularly toward male children, that are related to what it takes to satisfy the cultural pattern. We have to take time to try to educate the leaders first and then, with their permission, the people themselves.

I think some progress is being made. Just last week, with the Assistant Administrator for the Africa Bureau, I set up a joint task force so that we could combine our efforts to see what we could do to accelerate the rate at which education and action on the family planning question could be taken.

Mrs. **Schneider**. There have been some research exchange programs with some of the land grant colleges and also India, and I am wondering if those particular programs with India have been rather successful in developing different grains of cereals that have been helping India to become much more self-sufficient. Why have not other countries been as successful as India in this particular pursuit?

Dr. BRADY. Well, I used India as an example because it is the most evident one. Because of its size, you could clearly see what has been done. I have seen the change myself in the number of well-trained people that are available to them. However, at the same time I had the privilege in 1953 of helping to reestablish a college of agriculture in the Philippines, and that university, the University of the Philippines at Los Banios, as it is known now, is really, truly a de facto regional institution, not only in training undergraduates for the Philippines, but in training postgraduate students at the masters and Ph. D. levels. I have seen that institution raised from one that was the best they had but still inadequate for the purpose, to one that is now a regional institution.

In Indonesia a group of midwestern institutions under a consortium known as MUCIA likewise has helped that country move from a situation where, at the time of their independence, there were only a handful of people with Ph. D.'s, into a situation where they are now putting out thousands of well-trained people. Thailand is the same; I could give evidence as to what the university has done there. In Nigeria, it is the same; much of the progress they have made is tied back to the relations they had with U.S. institutions.

I would like to mention one thing, however: The development of those institutions in India and our association with them took 16 years. It is not something that you can do in 3 to 5 years.

Because of civil unrest as well as a decision that we made to move away from the degree to which we had had these institutional arrangements, we did not have the time in Africa that we had in India. Although India gives us by far the best example, there are other significant examples that could be used.

Mrs. SCHNEIDER. One final comment I would like to make, at least I know in my own district, which is very middle-class, blue-collar, hardworking, middle-income folks—and also in other places where I have been, whether it be Pittsburgh or wherever—you can turn on an evening talk show, a radio talk show, or I can hear on the streets from my constitutents, that there seems to be a losing of patience on the part of the American public with our contributions to foreign aid. In my own district there seems to be so much competition with illegal aliens or foreign workers. There is a real attitudinal change taking place now that, whereas in perhaps the past 20 years our country experienced great growth in productivity, we are now stagnating, because I believe we are moving into a different phase of civilization or existence or whatever.

However, you are accustomed to dealing with cultures that have as their personal philosophies and cultural philosophies, doing more with less. Do you see ways that you, as an agency, could be doing more with less?

Dr. BRADY. That is a very interesting question.

Mrs. SCHNEIDER. I try to make them as interesting as possible.

Dr. BRADY. I do not think there is any question but that this is what we continue to try to do. I have been faced, since I joined this

Agency, with a significantly reduced personnel level, and yet I have been asked to come in and mount an even stronger program in science and technology. Therefore, I did not approach this task by saying, "Well, I cannot do it. I do not have the resources." I have looked for alternate means by which we could utilize resources in the developing countries.

Mrs. **SCHNEIDER**. Are you finding those alternate means?

Dr. **BRADY**. We are developing programs that I think will make it possible for us to be more effective with what we have. I think this is true, particularly in the area of the program that we are talking about here in terms of science and technology, technology generation and development.

I would say, however, that we have to think in terms of investment. With regard to the institute that I led for 8 years in the Philippines, I believe we can show that every year there is between 2 and 5 billion dollars' worth of rice that is being produced that was not produced before that institute came into being. Much of that additional production can be traced right back to new lines, varieties, genetic materials that came from this center.

I am reminded in this regard of a group of Iowa businessmen and farmers who visited me soon after I went to this institute, and raised the question as to how much American money had gone into this institution since it started. I said, "Well, I really have not gone back and figured it out. It was set up by the Ford and Rockefeller Foundations. At the present time, the U.S. Government is putting in about 25 percent." However, I said, "I would like to make a wager with you. I would like to bet that all the money we have put into this institute in the last 15 years would not pay for that one B-52 bomber that was shot down yesterday in Vietnam." I said, "Where do we want to put our money, in having to fight people that come into power as a result of inadequacies of food, or do we want to try to help these people generate the capacity to produce their own food?" I would say it is just not a matter of either, it is either/or.

Mrs. **SCHNEIDER**. Thank you very much.

Thank you, Mr. Chairman.

Mr. **SCHEUER**. Thank you, Mrs. Schneider.

Dr. Brady, you are saying that you have operated on the assumption that less is more and that you can do more with less, and that you have been trying to do that. Can you elaborate a little bit more on that and give us some specific instances?

Dr. **BRADY**. I can give some very good examples. I think probably the most signficant approach that has been used to try to help people in the developing countries produce more food is through helping them to develop varieties of plants and strains of animals that will perform better with current inputs or, with a little extra input, perform twice as well.

The reason this is so important is that it does not cost much to provide a farmer with seeds. If you can breed into that seed genetic resistance to insects, resistance to diseases, tolerance of adverse soil conditions, flooding, and drought, you give the least expensive advanced technology that you could find anywhere in the world. That has been a common procedure that has been used by the U.S. universities and by the international centers. I think you can trace much of the technology generation to these new entities around which you can build a new cultural pattern.

Second, may I use the example of fertilizers. Before the marked increase in the price of fuel, fertilizer was so cheap that it really did not matter if you were not using it too efficiently. However, now that is no longer the case.

Mr. **Scheuer**. Most fertilizers do require high energy inputs.

Dr. **Brady**. The energy input is the reason the cost went up, because nitrogen is the primary element at issue here. When I was at the International Rice Research Institute we found that up to 70 percent of the commercial fertilizer that was applied to the rice crop was lost. We had taken all the energy and time and money to change atmospheric gaseous nitrogen into a form the plant could utilize, we put it on the soil, and because of the practices that they were using, 70 percent of it went back into the atmosphere as free, gaseous nitrogen.

The International Fertilizer Development Center in Alabama, the International Rice Research Institute in the Philippines, combined their forces to say, What can we do about this? Some very simple things have come out of this. In the first place, sulfur coating, putting a little sulfur around the urea, reduced the ability of organisms to change that urea to nitrate, making it impossible for the oraganisms in the soil to release it in the form of nitrogen gas. That is one way.

Another simple means of putting the nitrogen, and urea, down into the wet paddy and not on the surface, brought about a significant reduction in the loss of nitrogen. A third mechanism, also relating to nitrogen, was to turn to the legume. There has been a lot of work on soybeans, alfalfa, and clover in this country, but in the tropics relatively little has been done. The approach that has been used is a genetic one. I have been informed that on some of the edible legumes that are used, they found that there are certain types that have a higher nitrogen-fixing capacity, the ability to take nitrogen from the atmosphere and fix it in the nodules surrounding the roots of these plants, thereby giving a much higher yield and leaving the soil at least as well off as it was when the crop was planted and in most instances richer in nitrogen.

Now these are the kinds of efforts that we are addressing through the international agricultural research centers, U.S. universities, and national organizations.

Mr. **Scheuer**. Getting back to the subject of family planning that you discussed with Congresswoman Schneider, I take it you believe as I believed that the individual who tries to teach the farmer how he can maximize his production with new seeds and new techniques and what not, how he can maximize his productivity? Is that Outreach person who is the farm expert also the most appropriate person to begin to supply—or is that person an appropriate person—to begin to supply some concept of the balance between food and people and that piece of land, and the support, the maximum support capability in terms of people and mouths, of that piece of land?

Dr. **Brady**. Yes. I do not think there is any question about the absolute essentiality of confidence of the farmer and his family in the extension agent or anyone else who represents his government.

One of the problems I noted in 1953 to 1955 when I was in the Philippines, was that the farmers generally did not have much confidence in the extension service.

Mr. **Scheuer**. In ours, or in the Philippine extension service?

Dr. **Brady**. In the Philippine extension service, and it was merely because they had not seen evidence of those people providing them something that would really be useful. Now in my judgment, as soon as some technology was generated, when the extension worker went out there and asked the farmers to listen to him and accept this, the farmer then tried it. It worked, so the next time he came along and he suggested something with regard to another crop or another practice that they wanted to have the farmers adopt, they listened. I saw evidence of a night-and-day change from 1953 to 1973 in this attitude, so there is no question that the extension agent can gain the confidence of the family.

There is also no question that there is a need, through the extension service, to alert farmers to their needs beyond the production of food, since they look to the extension agent for information. Now in terms of the delivery of information about family planning, what this county agent can and in many cases is doing is to refer them to a small clinic. If the wife goes to a health clinic, she will be much more open in asking questions than she would be if she were asking a man who is trying to get them to use a new plant variety. However, this man, if they have his confidence, will know where this clinic is and say, "If you want that kind of information, these are the people in the health office, or in a special office, the population office, that can provide you with that assistance." He can even be a go-between to call attention to the clinic on some questions that may come up.

Mr. **Scheuer**. Now you talked about techniques of farming, and also I think you mentioned techniques of family planning that would be consistent with the religious, cultural, political, tribal, ethnic traditions, and mores and practices of these peoples in the developing world. Let's take the Philippine people as an example. I take it you feel that the insights you give them in farming should, to the best possible extent, be consistent with all of these factors that enter into their real world environment.

There are some traditions, I guess, that we really have to find a countervailing force to, such as the tradition that a man's macho can be measured by the regularity each year of another offspring, of another child. Would you think from that point, therefore, that just as we need new and more responsive research for agricultural technology that is appropriate to Third World needs, do you see any avenues for new family planning or contraceptive research that would be more appropriate and more acceptable and more sensitive to the various kinds of, as I said, cultural, tribal, political, religious inheritances that are a fact of life in the Third World?

Dr. **Brady**. Well, turning first to the question of the differences in culture, religious beliefs, and so forth, we recognize this to be a very, very important matter that we have to take into consideration. Under no circumstances do we want to try in any way to force or push someone to adopt any kind of technique which may be incompatible with their religious beliefs. That is the reason we emphasize education, to be sure they recognize what their choices are and to make available to them as many methods as we know of. That is one principle that we stand by.

Now with respect to the availability of methods that would be more acceptable, we do have quite a wide range of techniques available for contraception. In the area of natural family planning, which because of some religious constraints is very definitely desired in some cultures, we try to make information available on natural family planning and give opportunities to the family to see what can be done with techniques that would not make use of contraceptives.

At the same time, we make available information about contraceptives and in some cases actually provide supplies, so we do think we have a series of alternatives that are very good. At the same time, I think we would have to recognize that ideally there are even better techniques available, though not financed by AID. For example, one could inject some chemical, and for a period of a year, perhaps, the wife would not be able to conceive or the husband would not be able to make her conceive. It is possible that even better techniques could be worked on. We are aware of research that others are doing in this regard, and we are taking a very close look at it. We tend to work on the applied research side. Once something comes out of a very basic study we have been very active in trying to see to it that it is evaluated because the preliminary evidence suggests that the effectiveness of some of these new techniques is better than the ones we are now using. It's AID's general practice to provide to other countries only those contraceptives approved by the Food and Drug Administration for use in the United States. We want to be sure that these are thoroughly tested and that there are clinical trials before we are willing to try to use them.

I would not for a moment want to indicate that we do not need better technologies. I would simply say that those we have are good enough to bring down very significantly the rate of increase in population numbers.

Mr. SCHEUER. Right. Let's discuss for a moment your joint projects with international organizations. Can you tell us something about the types of cooperative projects and the level of cooperative activities that you have going now with the FAO, the Food and Agriculture Organization, the World Bank, the United Nations Development Program, UNESCO, the rest?

Dr. BRADY. I would be glad to comment on this because I think technology generation gives us the best example of our collaboration with these international organizations. The International Agricultural Research Centers are cosponsored by FAO, the World Bank, and UNDP, and by this cosponsorship, it is possible for the donors that are providing funds to these 13 international agricultural research centers to get together every year, at least once and sometimes twice, to listen to what these centers are doing, to see to it that they are responding to the needs of the people. That would be by far our most important interaction.

Mr. SCHEUER. Which of the U.N. agencies are involved in these International Agricultural Research Centers?

Dr. BRADY. The Food and Agriculture Organization, UNDP, and the World Bank. UNEP—the United Nations Environmental Program—has already also provided some funds. UNESCO provides funds not for what we call the core operating budgets but for special activities. When I was in the Philippines we had conferences organized in such a way that UNESCO could cooperate with us, particularly activities relating to nitrogen fixation. These are the organizations we deal with most in terms of agriculture.

Mr. **Scheuer**. Do you have, is there any input by UNFPA—that is, the U.N. Fund for Population Activities? That is the family planning agency of the United Nations.

Dr. **Brady**. Not directly to the international agricultural research centers, although we provide funds that you make available to us directly for UNFPA, about $32 million, and we work with them very closely. The Director General of that organization and I have had several conferences. We are cooperating with them very closely, not only by providing moneys but by working with them as they and we develop programs in the field.

Mr. **Scheuer**. In your view, how effective are the agricultural technology programs that these international agricultural research centers carry out, supported by FAO and supported by the World Bank and UNDP. How effective are they and how do you think they might be improved?

Dr. **Brady**. Mr. Scheuer, you must recognize I will give you a very biased answer, having served as director of one of those centers for 8 years, but I can indicate to you how that center and others are interacting with their counterparts in the national programs.

We do this primarily through coordinated networks of programs where activities are being carried out in each country. These are activities that their own government says are important enough that they want to put money into them. The international rice testing program is an example. Each year, more than 800 tests are run in different countries utilizing the best rices, not only those that come from the International Rice Research Institute but the best rices that come from other partners in this network. The data from these experiments are all fed into the International Rice Research Institute and then made quickly available to the other organizations, so that they find that a rice variety bred in Bangladesh is a very good performer in India. Even though at times you may find some political differences among countries, using this mechanism the scientists are able to freely exchange these materials with each other.

Now, you say, how does this get out to the farmer? In each one of those countries, if they see how this works internationally, they are more prone to develop the same kind of relationship within their own country. India, for example, is participating in this international network, and it also has a national network. All of the materials that appear good from the international programs are quickly made available at the country level.

The best evidence that I can give with regard to how this system is working is to make reference to IR-36. That is probably the most widely grown single variety of any major crop in the world. Certainly in Asia this is true. That came out of this system. It happened to have been developed at IRRI, but that is not important.

Through this testing mechanism, countries found where this variety would fit, and they immediately put it to work.

It has been largely responsible for Indonesia becoming self-sufficient in rice. That country was having to import large quantities of rice, mostly from its neighbors in Asia who use that type of rice, but now they are able to move ahead on their own. This came about as a result of the dissemination of this particular variety.

I could use the same example for potatoes with the International Potato Center located in Peru. Materials that they have gathered that have characteristics applicable around the world have been made available to scientists not only in the developing countries but in this country and in Europe as well. Therefore, the institutes serve as brokers, so to speak, where the best materials can be sent either to them or where they set up a mechanism by which these materials can be made available from one country to another. Perhaps an even better example might be given of what has happened in the case of wheat. This is reported in a book that I just received, and I would like to leave a copy of it.

Mr. SCHEUER. We would very much appreciate it if you would leave any of your literature that would be of interest to us. We would be grateful for that.

Dr. BRADY. I would be most pleased to do so, because this tells a good success story, including the success story in Pakistan and India. Within a period of about 5 years they have doubled their production in northwest India, and the same thing took place in other areas of the world.

The best evidence that the information is being used is what has happened in terms of production. We will see within the next 5 years, a similar development in cassava. We are already seeing in Latin America a development that could match this in beans, a very important crop for that area. I think we are seeing this also for some of the forage crops for which we are developing varieties in Latin America that will grow under very acid conditions. As a result, you will not have to come in with new chemicals, new lime, new fertilizer, in order to increase the holding capacity of pastures for the small farmer.

Mr. SCHEUER. That is the person we are interested in. The big agribusiness, agricultural industry is being very well looked after.

Dr. BRADY. They can take care of themselves.

Mr. SCHEUER. They can afford their own research. They have made tremendous progress. I suppose that is why we are the grainery for much of the world. Their needs have been fulfilled both through private research efforts, semiprivate, mixed research efforts, and government research efforts, and we are happy that that has happened. However, the deficit area is for research for the "little guy" as you call him, both in our own country and around the world, especially in the developing world, and this is what we are interested in.

We are way behind schedule, so what I am going to do is ask your permission to give you some written questions that we do not have time for this morning because we do have two other witnesses, and we will hold the record open for a week or 10 days or 12 days, whatever you need, and express our deep appreciation for your testimony. We are very grateful for your testimony. We will give you some additonal questions. We thank you very much, and we look forward to inviting you back here on future occasions. You are a very thoughtful and stimulating witness.

Dr. **Brady**. Thank you, Mr. Chairman. I hope you will excuse me. I would like to listen to my colleagues and I know they are going to be giving you even more exciting things than I, but I do have to go back and do a little work.

Mr. **Scheuer**. Very well. Thank you very, very much.

We will now hear from Dr. John Nicholaides, department of soil science, North Carolina State University in Raleigh, and Dr. Richard Harwood, the Rodale Research Center in Kutztown, Pa.

I might add that I have just been informed that Dr. Nicholaides has just returned from Southeast Asia in order to be at this hearing.

I am going to have to leave for a few minutes, and I am going to ask my colleague, Mrs. Schneider, to accept the chairman's gavel and I will be back in 15 or 20 minutes.

Each of your prepared testimony will be printed at the appropriate point in the record, so I would ask the two of you to take 10 or 12 or 15 minutes to give the highlights of your testimony plus react to anything you may have heard this morning, and then after you have both given us your testimony, I am sure that we will both have some questions for you.

Mr. **Nicholaides**. Thank you, Mr. Chairman.

Mrs. **Schneider** [acting chairman]. Won't you begin?

STATEMENT OF DR. JOHN NICHOLAIDES, DEPARTMENT OF SOIL SCIENCE, NORTH CAROLINA STATE UNIVERSITY

Mr. **Nicholaides**. I appreciate the opportunity to be here with you today. I would like to preface a slide presentation I have with a couple of comments.

The main point that I would like to stress in my testimony to you this morning is that our university, North Carolina State University, under AID funding has been able to develop some appropriate technologies for use in some very marginal soils of the humid tropics. This development has enabled small farmers in Peru to have available to them the technology for producing three consecutive crops per year over any number of years that they would care to do so, versus producing one or two crops on land that is normally subjected to shifting cultivation, and then returning that land to a forest fallow for a period of anywhere from 17 to 21 years. The problem is that population pressures now are forcing a shorter fallow period, and the soil does not have time to regenerate its fertility with that shorter fallow period. This is why this particular program is so very important.

Additionally, one of the things that Mr. Scheuer and, I am sure, you were referring to this morning in some of your comments would be the vital necessity of having programs such as ours and others that are funded by AID recognized as being part of our national security system. These particular programs have as much impact upon developments that occur in the developing countries as do many of our military programs. I will make some comments a little later regarding this.

I am going to talk with you about our tropical soils research program that has been funded by a number of U.S. AID contracts over the last 10 years and is still continuing under a U.S. AID grant. The area that we are primarily concerned with is in the humid tropics.

This is a map of most of the tropical portion of South America, and the area where we have been working, Yurimaguas, is here in the Peruvian jungle. We also have work in San Ignacio, Bolivia and under the Rockefeller Foundation in Manaus, Brazil, but I am not going to address that now.

This area of the humid tropics of South America is comprised of 75 percent marginal soils that Mr. Scheuer referred to in his opening statement. These soils are acid and infertile. We found when we first started the program, by going back into the jungle and surveying the soils, that the soils found in the Amazon jungle basin are very similar to those found in the Southeast United States, and for all practical management intents and purposes they are the same soil. In fact, they are classified as the same except for their temperature regime.

The site that was selected for our research is at the last large fluvial port on the headwaters of the Amazon River. It is a small town called Yurimaguas, Peru. The soils there and the climate, the crops, the socioeconomic conditions, are similar to many of those found throughout the upper Amazon region. An experiment station was established with the Peruvian Ministry of Agriculture in Yurimaguas. This slide shows about one-fourth of the area under experiments at the Yurimaguas station in the Amazon jungle of Peru.

We first looked at land-clearing methods, comparing the native slash-and-burn system used in migratory agriculture, incidentally a very productive system if the soil has time to rejuvenate itself. Comparing that system with the bulldozed clearing which a number of countries are now trying, we found in very short order that the crops growing on land cleared by the native slash-and-burn system were far superior to those found on the bulldozed land.

There are several reasons for that. One, quite obviously, with a burn there is some fertilizer value of the ash and the partially decomposed material. Also, the bulldozer will remove that very fragile and somewhat fertile layer of topsoil that is so important for crop production. Also, these soils, as are ours in the Southeast United States, are very subject to compaction by the heavy equipment, which means that the crop roots are not able to get through the hardpan created into the subsoil to utilize its moisture and limited nutrients. Therefore, our traditional slash-and-burn clearing produced crop yields superior to bulldozed clearing.

The big question then became how to maintain these crop production systems for continuous crop production. By taking soil samples and analyzing these in the lab in both Peru and North Carolina, we have been able to develop rotational cropping systems that enable continuous crop production over a number of years. On our left would be the native system, the 18th crop on the native system, which is producing no growth. In fact, the third crop on this native system looked exactly the same way. On our right, with the appropriate inputs and management, is the 18th consecutive crop on a given plot of land. We are now into our 28th consecutive crop on the same plot of land.

Therefore, monitoring the soil nutrient dynamics over time, has allowed us to identify and correct the soil fertility problems and to consequently continuously crop these marginal soils. Again, this is something that the native system does not allow.

That is very well and good, but what about the effects on the farmers? What is happening along that line?

We set out, starting back in 1978, a number of experiments on farms with the farmers and their families themselves actually implementing and managing these trials. We only told them how and gave them advice but they did the work. They looked at their native, traditional system versus two of our improved systems. One improved system was with improved seed, planting, spacing, and management, but without lime and fertilizers that are required. The other improved system was the improved seed, planting, spacing, management with judicious and rather small amounts of lime and fertilizer.

I am not going to show you any of the data but will just tell you that the on-farm trials that were managed by the smallholders themselves demonstrated the agronomic and economic validity of the Yurimaguas technology. To give you an idea of the economic validity of what we call the Yurimaguas technology or improved technology, again with judicious amounts of lime and fertilizer and proper management techniques, the 11 initial farmers operating with us could have realized a net profit of almost $2,800 per farm family on a 4-acre plot of land, according to our computerized economic analysis. The traditional systems in those areas give the farmers on about that same amount of land an annual net profit of $750. So there is quite a comparison.

One of the other interesting parts of this story is that the upper 25 percent of the families living in the slums of Lima, Peru have a family income of right at $1,500 annually, and here on a 4-acre plot of land, 11 farmers the first year had the potential of realizing a net profit of $2,800. I do not know that this will encourage some reverse migration, but if I were someone living in the slums of Lima getting $1,500 per year for my family, I would surely think very seriously about moving to the jungle area where I could produce more for my family.

We also moved into a program, combining efforts with the Ministry of Agriculture and the Ministry of Education, where we implemented these same trials on 28 schools around the Yurimaguas area. The children, their families, and the teachers themselves set out and managed the trials. In these 28 schools there were 646 farm families represented. At the end of the first year, over half of those families said that they wanted to try some of the improved technologies on their own lands. They were sold on the techniques.

We have also been looking at low-input crop production systems. Some aspects that Dr. Brady mentioned this morning have been very important in our program. The use of acid-tolerant varieties, particularly of rice and cowpeas, show good potential for minimum-input systems. In other words, if the crops are acid-tolerant, less lime will be required to be applied to the land.

For instance, in this slide which may even be an International Rice Research Institute variety, you really cannot see the difference between the acid and the limed plots because the rice is growing the same on both of them.

We feel that composting may be a partial substitute for some inorganic fertilization but it is very labor-intensive. Also, especially in the case of calcium and magnesium, our two liming materials, and in the case of potassium, the compost is not supplying enough of these nutrients to meet the crop demands. Again, it is very labor-intensive. We are having to take 10 tons of this compost material, apply it to a hectare of land each year, and still add calcium, magnesium, and potassium. We have tried encouraging the farmers to pick up some of this technology, but the farmers assure us that they would rather worry about carrying several 100-pound sacks of fertilizer to the field than moving 10 tons of compost.

We have been researching and having success with certain grass-legume mixtures that show promise for beef production in the area.

While we do not pretend to have all of the answers for the technologies that are necessary for this region, we do feel that we have found a number of them. There are constant second- and third-generation problems that occur that have to be dealt with, and this is the reason that long-term agricultural research has been so important in our country and will be so important in these developing countries.

The Ministry of Agriculture in Peru has taken a tremendous interest in the technologies that we have developed. The Peruvians have improved the port facilities, and the roads going into the region to be able to get the needed inputs in and the produce out to the larger metropolitan areas. They have established a fertilizer distribution plant in Yurimaguas, Peru. Along with North Carolina State University under AID funding, the Peruvian Government is establishing a training center at Yurimaguas whereby the farmers, the Peruvian researchers, and the Peruvian extension men can meet together, discuss issues that are important for all of them, and learn and extend these technologies to more farmers in the region.

The Yurimaguas technology is having an impact on the smallholders as far as their crop production and income are concerned, and on those who are choosing to go on a larger scale. This man has taken the technology and is now using it on about 10 acres of land, and having a very good income from it.

As a consequence of this—and I think this is one of the most important parts of the story that I have to tell—it does not take a genius to realize that if a farm family can produce on a given plot of land, say 4 acres, what they would normally have to do with their shifting cultivation system on 80 acres, this means that less of the jungle will be cleared. There are a number of environmental and ecological concerns related to the jungle clearing. Use of the Yurimaguas technology means that for each hectare of land continuously cropped, there are approximately 20 that have the potential of retaining their ecological integrity. Thus, there can be increased food production and less rain forest clearing.

Therefore, all of this I think offers hope for the smallholders in various areas of the humid tropics. North Carolina State's program, because of some of the successes that we have enjoyed over the last 10 years, has now moved into a leadership position for extending this technology throughout the humid tropics, depicted on this world map by the green areas. We are involved in Indonesia now, trying to adapt some of these Yurimaguas technologies to some of the transmigration areas where they so desperately need help.

This is the end of my presentation. I will be glad to entertain any questions from you. Thank you.

Mrs. SCHNEIDER. I would just like to ask a brief question, and then maybe we will hear from Dr. Harwood. Then we will ask questions of the two of you at the same time.

Can you give me an estimate of approximately the total cost of the research and technology transfer with Peru that we have just seen?

Dr. NICHOLAIDES. Yes. We have been working for the last 10 years in this area. I did not come into this program until 1977, so I am not going to be able to speak on the earlier years, but the cost has averaged right at $600,000 annually since I have been in the program. Therefore, if you want to extrapolate back to the other years I would say that probably over a 10-year period you would be talking about $6 million.

One point that is very important here is that the Peruvian Government is now putting in more cash than U.S. AID in this program, and this is not even counting the salaries of the Peruvians who are working with us.

Mrs. SCHNEIDER. I see. One of the things that is very frustrating, as a new Member of Congress, that I have witnessed is the debate on the floor when one discusses the value of this kind of investment. It seems to me that there are some awfully strong arguments for continuation of some programs, but regrettably those cases have rarely been made. I think that if we could ever do or if you could ever do a cost-benefit analysis as to what it would cost us and the benefits received from this kind of technological transfer, and helping those people help themselves versus just general distribution of grains and foods and that kind of program, I think that that would help to inflate your argument or bring more credence to it because when one is talking—I guess you were the one who mentioned the whole impact on national security. This is a way to factor in that argument.

Dr. NICHOLAIDES. This is one of the very difficult questions to address, and if I might take just about 2 minutes to speak to this, I think that it could be pertinent for the discussion. It is very easy in military matters to look at the arms buildup of one side versus another. It is very easy to do cost-benefit analysis on that, but it is more difficult to quantify the natural resource and ecological stresses that systems undergo.

Those stresses, which are becoming very acute in many of the developing countries, are producing and have produced in the past economic stresses which sometimes shake the very foundations of the political systems of those particular countries. A very good case in point is the fall of the centuries-old dynasty in Ethiopia several years ago. That dynasty, which was friendly to the United States, did not fall because there was a Communist government or a Communist plot trying to overthrow that particular government. The Communists, the Marxists, did come in and benefit from a situation that occurred because the government was not able to produce enough food to feed its own people.

In the case of Peru, Representative Schneider, I am sure that you are more aware than am I that Peru is regarded as the very anchor and the strongest link in the Andean chain countries, and the strongest U.S. supporter in that area. Peru has just returned to democracy's fold after a 12- or 13-year socialistic military rule. It is very important for the United States that this democratic process be allowed to continue in Peru. If that government can continue to provide technologies for its people to become self-sufficient in food production once again, then that government has a much better chance of staying in power than it would under other conditions.

These are some of the reasons that I think certainly a number of you, like yourself and Chairman Scheuer, are very familiar with, but there are others in Congress that do not know or realize this. We will do our best to try to get the point across. We can try a cost-benefit analysis but again, that is a very difficult thing because we are talking about biological systems versus military hardware.

Mrs. **Schneider**. I agree with you 100 percent. Seeing as how this committee also handles environmental research, there is always the question of cost benefit there and how do you determine the costs of acid rain on human health or on other resources, such as prime agricultural land or bodies of water or whatever. However, it seems to me that this is the framework within which decisions are being made, and so to whatever degree we can try to fit our arguments into that framework, we can make our case even stronger yet.

However, I have found your testimony to be very insightful, and I think it is a most impressive program that you have been involved in.

Now, perhaps, Dr. Harwood, you would be good enough to give us your testimony. As a longtime reader and supporter of Rodale Press, whether it be on the alternative energy technologies or composting or farming or whatever, I feel right at home and I am looking forward to your testimony.

STATEMENT OF DR. RICHARD HARWOOD, RODALE RESEARCH CENTER, KUTZTOWN, PA.

Dr. **Harwood**. Thank you, Madam Chairman.

I had planned to start my testimony with a short illustration from the State of New York. Since it is very illustrative of the points I want to make, I think perhaps I will anyway.

A former mentor of mine and many other agronomists and soil scientists, Dr. Richard Bradfield, was a professor of soil science for many years at Cornell. Back in the fifties he used to make the statement to his students that there is more potassium in the soils of upstate New York than in all the mines of North America combined, and our job as soil scientists is to figure out better ways of getting it out.

Unfortunately, over the last two or three decades as we have had very plentiful resources, we have sort of lost sight of that mandate. In addition to this, we see areas—like on Long Island, for instance—where we are having movement of nutrients and other materials from the production fields into the groundwaters, to the consternation of many of the residents who are trying to drink that water. We are looking for solutions to some of these problems.

We as organic researchers have, by accident perhaps, stumbled upon technologies which provide some of the answers. Now I do not want to detract at all from the high energy flow kinds of systems, part of which Dr. Brady and Dr. Nicholaides have talked about. I worked for many years in those myself, and I am very familiar with some of the projects.

The project you have inherited in Sumatra, trying to correct the World Bank disaster where they have gone in, precisely, with bulldozers—unfortunately, and the saying is very prevalent among organic practitioners—we are using bulldozer technologies in many different ways. We come in and we try to dominate our environment in production.

Well, now let me just briefly go to some of the research that we are doing. Perhaps the most relevant, and that which is giving us the clearest insight into alternative technologies, is the look that we are having right now at whole farms and whole farming systems, and primarily within the United States. There are some 30,000 to 40,000 farmers within the United States who call themselves "organic," using the very broad USDA definition.

These farmers are minimizing the inputs to their farms. They avoid the use of synthetic inputs and minimize the use of any inputs, not that they are completely self-reliant. They will use pesticides on occasion to some extent. I am not here to argue the merits of using pesticides or not using them, or to argue the differences in food quality and what not that may come from those systems, but I think it is interesting to look at those farms.

As we have researched them, several points have come to light. Now there are four or five projects, university projects as well as our own in collaboration with Penn State University, that have been looking at these farms. We find demographically that those farms have approximately the same size. They have about the same variability in types of enterprises as agriculture in general.

It is little known, for instance, that 3 percent of the U.S. table grapes are produced completely organically. They are marketed through normal channels. There are 2,000-acre organic farms and there are 50-acre organic farms.

As we look at those farms, we find that on the west coast they tend to be nonlivestock associated. They are crop-oriented kinds of farms, speciality farms. As you go through the Midwest and on into the Northeast, more of them tend to be integrated livestock operations, but the characteristics of them are very interesting.

First of all, they are very management intensive. Now the difference is very similar to that between integrated pest management and weekly spraying according to a cookbook formula. The intensive or integrated pest management requires very careful monitoring. It is very much management intensive. If we apply that same process to the control of weeds, and especially and particularly to the control of fertility and the cycling of nutrients, you have somewhat of a picture of what an organic farm is like.

As we look at the economics of that kind of an operation, then, we see that the management and perhaps machinery costs are somewhat higher, but the cash input costs are considerably lower. Now if we take one particular study done of Midwestern farms, comparing 50 paired samples, we find that there was a 60-percent reduction in energy inputs on the organic farms per dollar of produce—a 60-percent reduction, now, which is significant.

A study which just came to my desk yesterday of 25 pairs of Minnesota farms indicates that the energy reduction is between 35 and 45 percent on the organic farms, a considerable reduction in energy per dollar of produce coming from the farms. The variable production costs on those farms are significantly lower.

I mentioned that the labor and management costs are higher. The total cost of production is somewhat lower. The yields vary anywhere from about the same to some 10 percent less, or the total productivity of the farm, some 10 percent less. You can find individual examples where the yields are as much as 20 or 30 percent above those of neighboring farms.

However, the most significant thing, and I think that is very relevant to your hearings here, is that inputs are drastically reduced. Now this reduction in inputs, the reduction in energy inputs, comes about by structuring the farm to get particular kinds of interactions. There are certain crop combinations that are grown, one crop after another in rotation, according to fairly well-defined schedules.

Let me give just one example as to how that interaction will work. In Pennsylvania on the organic farms we commonly see wheat, winter wheat, rotated with corn. The weed control costs in that rotation for the corn are reduced by about one-third, and the weed control cost in the wheat is just completely eliminated. There are no weeds in the wheat in that rotation, so there is a significant saving in weed control costs due to the rotation.

OK. There are several benefits, now, from that integration. There are few conventional scientists who would disagree with those benefits. I think the point that needs to be made, though, is that we have grossly underestimated the extent of those interactions and their place in today's agriculture.

Now I might just speak for a minute about the nutrient use efficiency. We are concerned about fertilizer use. The organic philosophy has many things to say about nutrient use and nutrient flow and nutrient cycling and the things that you should do and should not do. There is a regular, almost a religion that has built up around this.

As we have researched it, we have found that there are significant differences between the systems. I have given in my testimony, in the figures, just a couple of illustrations that come actually from USDA research, where there are three or four isolated USDA projects researching organic agriculture. This, I think, is a dramatic one because it illustrates a point that is extremely important.

The Washington State University people—Dr. Papendick, in particular, who is a member of the USDA Study Team on Organic Agriculture—have been looking at a wheat farm that has been organic since 1912, I believe. It is an 800-acre wheat farm in the Palouse. This is in an area where soil erosion ranks among the highest locations in the United States. This farm is on a very fertile soil, a very deep soil of relatively recent origin, but it is somewhat deficient in phosphorus. It has adequate potassium.

For 75 years this organic farm has been operated with no input of nutrients to that farm whatsoever. No nutrients of any kind are brought onto the farm, other than what are deposited there by wind erosion, perhaps, from the neighboring farms, but they are not bringing anything onto that farm. After 75 years of mining of that soil—and the neighbors claim that his yields are as high as theirs, the records are not too good on this but the feeling is that the yields are very comparable—this farm has 30 percent higher potassium and 40 percent higher phosphorus levels in the soil than the neighboring farms, farms that have been fertilizing heavily for the last two decades, at least.

Therefore, this illustrates a point that these organic systems, then, have efficiencies in fertilizer use. They have major impact on the vertical flow of nutrients within the soil profile.

Mr. **Scheuer**. Excuse me. I must leave now to appear before the Rules Committee. What I suggest as a possibility, Dr. Nicholaides, you have completed your affirmative testimony; you go ahead, Dr. Harwood, and complete your affirmative testimony. We have read your testimony, in any event.

Dr. **Harwood**. OK.

Mr. **Scheuer**. Then I should be back within 15 or 20 minutes, and then we will have time for some questions. I apologize, but these are the last 2 days, and things are flying thick and fast.

In the meantime, our science consultant, Dr. Jim Greene, will ask any questions that are appropriate. Thank you.

Dr. **Greene**. Please continue.

Dr. **Harwood**. The point that I am making is that we have a laboratory right here in the United States of some 30,000 to 40,000 farms that have some rather surprising characteristics which would well bear looking at. I think we are learning from these farms that there are some extremely important lessons to be learned that would apply to some of the problems that we are having here in the United States, certainly, as well as in Third World countries.

I might just mention two or three other kinds of things that we are doing. We find that as we stop using intensive inputs on a field that has a long-term history of conventional use, that that stoppage is extremely disruptive. It is common knowledge among organic practitioners around the world that it takes from 3 to 5 years to convert a field back once it has been under heavy use of conventional fertilizers and pesticides. This is almost universally accepted. We do not know why. We have little documentation of this.

We are finding in our own trials—by the way, there are two locations in the world that we know of that are researching this problem—we are finding that the differences seem to be related to the form of nitrogen in the soil, but there are major differences. We find soils that under conventional use are apparently very fertile, almost identical to a field just across the fencerow which has been farmed organically, yet they will react completely differently when fertilizer is withdrawn or nutrients are withdrawn. We want to know why, and to know what really is the impact of these conventional practices.

This has immediate relevance to countries like India. We have been visited within the last few weeks by two students from Ohio State University, sons of a farmer in the Punjab in India. They tell us that their father this year cannot buy nitrogen fertilizer for his wheat, that it is just not available in the country. They say that their yields now are lower than they were before the advent of the new varieties and before they started using the conventional fertilizers.

They are experiencing what we in the organic field call "cold turkey withdrawal pangs." There are some things that they can do to ease through that transition. There are some things also that could be done, some technologies, some ways of cycling nutrients in, that perhaps are not as disruptive.

I could cite an example of a farmer that I say in tropical Costa Rica, along the Pacific coast, on an extremely poor soil, very similar to those of Brazil, where nutrients are absolutely needed. An input of nutrients is needed to grow good crops. This farmer had been growing two crops of corn a year on a field that was of such low pH, that was so acid, that theoretically corn would not grow.

We saw that he had a rigid furrow system of growing the crops, where he would concentrate all of the organic matter, the crops residue, the weeds, in the furrow between the corn rows, he would cover that with soil with his hoe and plant his next crop of corn right down that newlymade ridge. What he had done, in effect, was to pull the nutrients over a long period of time from the soil, concentrate them in plant biomass, and then keep them in that biomass and keep them away from the general soil mass, a very neat way of structuring nutrient flow within the field. We think that there are similar things happening in these organic systems.

Just a couple of other technologies that I will briefly mention: We are working with insect repellant plants and insecticidal plants. Pyrethrum is an extremely effective botanical insecticide. The crop will grow not only in Ethiopia and in parts of Africa where it is grown commercially, but it grows very well in the United States. It could grow in many countries. Crops like neem, from India, riania, from the Caribbean, rotenone, grow just beautifully in many environments. There are many countries with foreign exchange problems which could have very effective insecticide industries based on their own production of these botanicals. I think this has been overlooked.

We are about to face a crisis in nitrogen on a worldwide basis. Our own Fertilizer Institute tells us that within 3 to 4 years we will be hitting $1 a pound on nitrogen. I do not think that will happen because before it does, biological nitrogen begins to enter the picture in a much more strong way, and yet we are not looking seriously enough at the use of biological nitrogen. Our traditional research systems are giving lip service to this, I think, but in the meantime farmers in Delaware alone, on corn this year, 140,000 acres of corn will be self-sufficient in nitrogen using legumes. We are just not paying enough attention to these technologies.

The most important factor, however, is that we are simply not giving the mandate to our scientists to look broadly enough at enough options. A person who looks at organic agriculture today, or in many cases, sadly enough, within the scientific community, a person who goes far enough astray into a different paradigm, into a different model, a different way of thinking, is not only criticized but has real pressure brought to bear on him, if he can find the resources and money to research that area.

We are just not open enough to a broad enough range of alternatives and again, especially as we look beyond the accepted paradigm. I would like to end my testimony there and will be glad to answer any questions, then.

Dr. **Greene**. Thank you very much.

I would point out that a rollcall vote is now in progress, therefore we will take a 15- or 20-minute recess. Thank you.

[Whereupon, at 11:05 a.m., the subcommittee recessed, to reconvene at the call of the Chair.]

APPENDIX

Questions for Dr. Brady

Food Supply

1. On page 1 of your testimony, you indicate that food production and consumption in developing countries is well below the U.N. Food and Agriculture Organization's (FAO) minimum nutrition standards of 2,000 calories per person per day.

   A. Do you have any information on the number of people who fall into this category worldwide?

   B. Are there any studies that project what the level of food production will be over the next twenty years in these developing countries?

   C. One of the causes of food shortages is, of course, increasing population. Do the AID programs in appropriate technology transfer address the problem of increasing population? If so, how?

AID and Land-grant Universities

2. On page 2, you state that AID assisted in establishing a research partnership between Indian agricultural universities and U.S. land-grant universities. The end result of their research efforts were the production of high-yielding cereals which revolutionized India's food production.

   A. Why, for example, has this program been so successful while programs in other countries are not successful?

   B. On page 3 you indicate that steps have been taken to enhance the participation of U.S. universities in AID projects. Does this include the 1890 or predominantly black universities? If so, to what extent?

Long-Term Plans

3. On page 3 you state that within the Agency a policy paper on agriculture strategy is being developed. You also indicate that high-priority research areas are being identified.

   A. Please give us a status report on these projects? When can we expect a final report?

   B. Are the long-range research needs in appropriate technology being included in AID policy?

Small Farm Technology

4. On page 4 you state, "We must help increase the level of knowledge and applicable appropriate technologies available to small producers. We must also strengthen the institutional process of getting those technologies adopted in the LDC's (less -developed countries).

   A. Would you give us some more information on the programs to transfer the knowledge and technologies to small farms?

   B. What mechanisms do you use to gain acceptance of these technologies in the less-developed countries?

Applying Agriculture Technology

5. On page 5 you state, "Most U.S. based knowledge and technology cannot be 'transplanted' directly without substantial additional research. Therefore, we help finance research directly aimed at developing new knowledge and technology specifically applicable to conditions characteristic of developing countries generally.

   A. Is this research conducted in the United States or in the developing country?

   B. Are the final research results applicable to farms in the United States as well as to farms in other countries?

Research Projects

6. In your testimony you list several research activities underway. Could you provide us with more information on the direction and level of projects on,

   A. Integrated Pest Management
   B. Genetic Resistance
   C. Fertilizer
   D. Soil Erosion
   E. Postharvest Food Losses

Low-Water Agriculture Technology

7. One research project supported by AID is being designed to help Egypt with arid land agriculture. The research is designed to seek appropriate technology for increasing agricultural production under low water, low energy conditions.

   A. What is the status of this project?

   B. Can the research results be applied in other countries? in the U.S.?

International Cooperation

8. AID has many joint projects with international organizations.

   A. Would you briefly outline the types and level of cooperative programs with the U.N. Food and Agriculture Organization (FAO) and with the World Bank?

   B. What are the future plans for joint research projects with these organizations?

   C. Based on your experience, how effective are the agriculture technology programs supported by FAO and by the World Bank?

FOOD SUPPLY

Item No. 1. On page 1 of your testimony, you (Dr. Brady) indicated that food production and consumption in developing countries is well below the U.N. Food and Agriculture Organization's (FAO) minimum nutrition standards of 2,000 calories per person per day.

Question A. Do you have any information on the number of people who fall into the category worldwide (of below 2,000 calories per person per day)?

Answer: The World Hunger Commission Report indicates one billion people, which is estimated to be one-fourth of the developing countries' population, are below the 2,000 calories per person per day. The Commission based its report on World Bank figures.

Question B. Are there any studies that project what the level of food production will be over the next twenty years in these developing countries?

Answer: The best source for projections of agricultural and food production to the year 2000 is the UN/FAO report titled "Agriculture: Toward 2000" in which trends are analyzed and projections are made on a variety of commodities from both developed and developing country perspectives. The latest edition is dated 1981. Trends indicate continued increases in food production, but projected increases are not sufficient to off-set increases in demand and need, especially in Africa.

Question C. One of the causes of food shortages is, of course, increasing population. Do the A.I.D. programs in appropriate technology transfer address the problem of increasing population? If so, how?

Answer: No, we do not attempt to address population increases by combining population programs with appropriate agriculture technology transfer or similar programs. Rather, we fund programs that serve rural populations on a broad basis. Rural health clinics and mobile clinics are examples where family planning is offered as part of general health care. Other population programs for rural areas include commercial retail sales of contraceptives and community based distribution of contraceptives.

The Office of Population, Bureau for Science and Technology is now planning to incorporate present agricultural extension workers in an expansion of a family planning operations research project that is now underway in rural areas of Sudan. This expansion is planned to begin in 1983.

A.I.D. AND LAND-GRANT UNIVERSITIES

QUESTION: On page 2, you state that A.I.D. assisted in establishing a research partnership between Indian agricultural universities and U.S. land-grant universities. The end result of their research efforts were the production of high-yielding cereals which revolutionized India's food projection. Why, for example, has this program been so successful while programs in other countries are not successful?

ANSWER: While India has been the most successful, we should not infer that others have not been successful. For example, four institutions in Brazil as well as others in Pakistan, Thailand, and Turkey has also been successful.

The Indian experience was successful because of three main elements:

(1) From the beginning, the U.S. Government and the Indian Government jointly recognized and committed themselves to making the major reorganizations required of the agricultural institutions despite the immense bureaucratic changes entailed.

(2) A.I.D and the universities worked very closely as one partnership over a sustained period of time--16 years. This meant that all important actions were planned and implemented cooperatively with the universities putting forth their best efforts, including high caliber, long-term assignments of staff with strong home base support.

(3) The Indians had an established Central government budget system for earmarking their funds to assure a source of financial support for the program.

QUESTION: On page 3 you indicate that steps have been taken to enhance the participation of U.S. universities in A.I.D. projects. Does this include the 1890 or predominantely black universities? If so, to what extent?

ANSWER: Yes, strengthening grants have been awarded to nine minority institutions, such as, Florida A&M, Alabama A&M, North Carolina A&T, Tennessee State University, and Virginia State University.

These grants have been made on a concessionary basis.

LONG-TERM PLANS

Item No. 3. On page 3 you (Dr. Brady) state that within the Agency a policy paper on agriculture strategy is being developed. You also indicated that high-priority research areas are being identified.

Question A. Please give us a status report on these (high-priority research areas) projects? When can we expect a final report?

Answer: An Agency agricultural policy paper has been approved which requires renewed efforts to identify, transfer and adapt appropriate technologies. Within the terms of this policy, a strategy paper is being developed. The policy paper describes what A.I.D. proposes to do and the strategy paper provides guidance regarding how A.I.D. proposes to do it. A substantial portion of the strategy paper is devoted to agricultural research and extension. It is anticipated that the draft strategy paper will be completed by November 15, 1982 and a final paper by early 1983. Agriculture research and technology transfer projects will be based on the priorities set forth in the strategy paper and on special reviews to establish Agency agricultural research priorities.

Question B. Are the long-range research needs in appropriate technology being included in A.I.D. policy?

Answer: The Bureau for Science and Technology is currently identifying agricultural research priorities to be implemented in future years. A team of outside experts and scientists are being brought together to evaluate existing programs and to suggest a revised set of priorities for research in agriculture to be supported by A.I.D. The objective of the review is to improve focus and concentration of ongoing research and add new topics for attention.

SMALL FARM TECHNOLOGY

Item No. 4. On page 4 you (Dr. Brady) state, "We must help increase the level of knowledge and applicable appropriate technologies available to small producers. We must also strengthen the institutional process of getting those technologies adopted in the LDC's (less-developed countries).

Question A. Would you give us some more information on the programs to transfer the knowledge and technologies to small farms?

Answer: All programs sponsored by centrally funded research and development assistance activities are designed to develop and deliver useful information to farmers in the recipient countries. Most programs are aimed especially at the needs of the small farmer. Some examples of the effects of these programs are:

A majority of the rice grown in Southeast Asia is the improved varieties from germplasm provided by the International Rice Research Institute and adapted by LDC national rice programs. Soybean varieties developed through A.I.D. sponsored work at the University of Illinois are used by small farmers in Egypt, India, Ecuador, and Zambia. Farming systems research and extension projects designed especially for the small farmers are being carried out in Tanzania, Niger, and Swaziland.

A.I.D. sponsors numerous training activities designed especially for recipient country personnel who are engaged in information delivery to small farmers. This training activity will be a major part of the new Farming Systems project .

Question B. What mechanisms do you use to gain acceptance of these technologies in the less-developed countries?

Answer: Small farmers are visited by teams of experts and scientists to determine, together with the farmers, what is needed for improving crop production. Research is then conducted at the farm level on improving technologies for increased production. Extension agents are trained to disseminate the new or improved crop technologies.

APPLYING AGRICULTURE TECHNOLOGY

Item No. 5.	On page 5 you (Dr. Brady) state, "Most U.S. based knowledge and technology cannot be 'transplanted' directly without substantial additional research. Therefore, we help finance research directly aimed at developing new knowledge and technology specifically applicable to conditions generally characteristic of developing countries.
Question A.	Is this research conducted in the United States or in the developing countries?
Answer:	Research funded under the Bureau for Science and Technology is conducted both in the United States and in the developing countries. Farming systems research projects are carried out in the LDCs with the emphasis on research on farmers' fields and with farmers' participation. This approach integrates work with researchers, farmers, and extension agents in LDCs to strengthen the transfer of technology to limited resource farmers. Research conducted in the United States and disseminated through networks of collaborators in the LDCs includes research at Oregon State University on Spring and Winter Wheat, at Montana State University on Control of Barley Diseases, at the University of Illinois on Improved Varieties of Soybeans.
Question B.	Are the final research results applicable to farms in the United States as well as to farms in other countries?
Answer:	Basic research results are applicable everywhere. Much of the applied research will also be useful to farms in the United States. For example, under the Collaborative Research Support Programs in beans/cowpeas and sorghum/millet germplasm will be identified for improved yield, pest resistance and resistance to environmental stress which are also problems U.S. farmers face.

RESEARCH PROJECTS

Item No. 6. In your testimony you (Dr. Brady) list several research activities underway. Could you provide us with more information on the direction and level of project on Integrated Pest Management, Genetic Resistance (Engineering), Fertilizer, Soil Erosion and Postharvest Food Losses?

Answer A. Integrated Pest Management - The Agency is actively promoting the essentials of good pest management by placing special emphasis on the combined use of chemicals (pesticides) and non-chemical controls with the ultimate goal of decreasing the use of pesticides to an absolute minimum. The 1983 budget for centrally funded research and technical assistance requests $2.0 million for this work.

Answer B. Genetic Resistance (Engineering) - Breeding projects sponsored by the Bureau for Science and Technology are actively using genetic engineering for developing varieties resistant to disease and insects. Plant breeding techniques are used to increase crop production. Tissue culture techniques are helping select varieties that have high tolerance against environmental stresses. The 1983 budget for centrally funded research and technical assistance for Plant Genetics requests $3.0 million.

The Science Advisor's Office is funding a research study at the University of Hawaii to determine whether rhizobia adapted to stress soil conditions can be genetically engineered to be more effective nitrogen fixers. Some countries, such as India and the Philippines, have organized special groups to work with these newer biological techniques and cooperative efforts are anticipated.

Answer C. Fertilizer - The International Fertilizer Development Center has been working on ways to make fertilizer more efficient. Sulfur-coated urea and supergranules can almost double the yield of rice per pound of nitrogen applied. Research is also focused on use of non-conventional phosphates. A.I.D. provides $4.0 million annually to support the IFDC.

Answer D. Soil Erosion - We do not have a separate project which focuses on soil erosion. This area is included in several projects. For example, under the Soil Management Collaborative Research Support Program, erosion control is a critical technical problem being studied. The Soil Management Support Service project with the USDA Soil Conservation Service provides the technical services of U.S. scientists to help conserve and manage vital soil resources of the developing countries.

RESEARCH PROJECTS

Answer E. Postharvest Food Losses - Food conservation and the reduction of postharvest food losses is receiving greater attention by the Agency. The two year old Postharvest Institute for Perishables (PIP) at the University of Idaho is providing technical assistance and training to LDCs in the areas of improved storage, marketing, processing, packaging and exporting of root, tubers, fruit and vegetable crops.

Kansas State University is providing technical assistance and training for the improvement of postharvest grain systems. Denver Wildlife Research Center, Department of Interior has effectively developed rodent and bird control capacity in several developing countries. The research element of this project is being phased down and in the future more emphasis will be given to providing the services of scientists to the LDCs. The FY 1983 budget for centrally funded research, and technical assistance programs in Postharvest Food Losses requests $1.5 million.

Under a new FY 1983 postharvest project three countries will apply a new methodology to help policy planners decide how best to utilize scarce financial and human resources to minimize wastage of basic grains after harvest.

In addition, A.I.D.'s postharvest contractors are being linked in cooperative projects. Technical guidance is being provided to selected Private Voluntary Organizations (PVOs) such as CARE. This new approach of networking A.I.D.'s postharvest contractors with PVOs is expanding the outreach and dramatically increasing the ability to conserve the desperately needed food resources of developing countries.

LOW-WATER AGRICULTURE TECHNOLOGY

Item No. 7. One research project supported by A.I.D. is being designed to help Egypt with arid land agriculture. The research is designed to develop appropriate technology for increasing agricultural production under low water, low energy conditions.

Question A. What is the status of this project?

Answer: This low water technology project in Egypt is in the planning/design stage.

Question B. Can the research results be applied in other countries? In the U.S.?

Answer: The principles of production practices developed for increasing agricultural production under low water technology, low energy conditions will be applicable under similar environmental conditions elsewhere in the world, including the U.S.

INTERNATIONAL COOPERATION

Item No. 8. A.I.D. has many joint projects with international organizations.

Question A. Would you briefly outline the types and level of cooperative programs with the U.N. Food and Agriculture Organization (FAO) and with the World Bank?

Answer: A.I.D. cooperation and collaboration with these two international organizations cover a broad spectrum of development-related activities. Technical specialists as well as the administrative staff of A.I.D. are in frequent contact with counterparts in both organizations through visitations, conferences, seminars, workshops and other means to facilitate the flow of information regarding programs, techniques and experiences covering the full range of disciplines identified with science and technology programs. These informal methods of collaboration and interchange provide the basis for developing inter-organizational activities that are generally characterized by the illustrations which follow.

Examples of cooperative activities with FAO include a world-wide effort in the field of improved post-harvest technology; an African Sahel program in plant protection that is mostly financed by A.I.D., but implemented by FAO; a joint program for establishing meteorological stations in Africa; a world-wide program to increase yields and encourage rice production; and a joint research program to control the tsetse fly. In addition to broad programs of this type, A.I.D. has numerous working relationships with FAO that are country specific and where coordination and cooperation takes place at the mission level in the A.I.D. organization. The FAO forestry projects in Senegal and Costa Rica which are receiving substantial A.I.D. support are illustrations of such arrangements.

The principal cooperative interface with the World Bank involves A.I.D. participation in the Consultative Group on International Agricultural Research (CGIAR), the organizational framework under which a substantial research program involving 13 research centers located throughout the world is financed and managed. A.I.D. provides about 25 percent of the core support of this effort while the World Bank provides about 10 percent of the direct financial support along with facilities and staff for the Secretariat. Coordination between development activities of A.I.D. and specific country projects financed through the World Bank is also a frequent occurrence when the programs of the two organizations coincide or overlap.

INTERNATIONAL COOPERATION

Question B. What are the future plans for joint research projects with these organizations?

Answer: A.I.D. will continue its efforts of interchange and dialogue with these organizations at both technical and managerial levels to identify broad areas of research activity as well as specific projects where joint effort may have synergistic effects in terms of producing a research output that will more fully meet the needs of developing countries. A.I.D. intends to maintain its involvement in and support of the CGIAR research network in collaboration with the World Bank and other international and national organizations. We are also currently engaged in discussions with the World Bank on the development of an International Forestry Research Institute Network designed to coordinate and strengthen research capability in this area. While we have no definite future plans for cooperative research with FAO, we will also continue to be alert for potentials for cooperative research with this organization.

Question C. Based on your experience, how effective are the agriculture technology programs supported by FAO and the World Bank?

Answer: We believe the agricultural technology programs of both organizations are effective. The investment oriented programs of the World Bank are generally preceded by extensive and thorough feasibility studies and supported by technical assistance during implementation phase.

The FAO, also appears well attuned to development needs for agriculture in various country settings, and effective in its efforts to improve the technology of agricultural production.

Clearly, the difficulty involved in closing the gap between world food needs and world production capability suggests that much remains to be done. Given constraints on funds and technical staff, more effective methods of achieving higher agricultural productivity in the less developed nations are continuing challenge to these two organizations as well as A.I.D.

ANSWERS TO QUESTIONS FROM THE U. S. HOUSE SUBCOMMITTEE ON NATURAL RESOURCES, AGRICULTURAL RESEARCH AND ENVIRONMENT

John J. Nicholaides, III

Deforestation

1. On the first page of your testimony you indicate that shifting cultivation is a primary cause of the clearing of the Amazon Basin rainforest.

   A. Does this mean that an area is cleared, farmed for a few years, and abandoned?

   Yes, except the farming is only for less than a year, usually with a two-crop maximum. The abandonment to allow these marginal soils time to regenerate their fertility has been for a 17-21 year period, but now population pressures throughout the humid tropics are forcing a shorter fallow period which is insufficient for soil fertility regeneration. Thus, an ecologically stable system is becoming an ecologically unstable one. This is the reason that a continuous cropping alternative is so important (see testimony on page 38).

   B. How long will it take the land to recover from the effects of this shifting cultivation?

   On these marginal soils which comprise 75% of the Amazon Basin, usually 17-21 years are required to regenerate enough fertility to support only two consecutive crops. Then the process is repeated as the small farmer abandons that plot of land and moves further into the virgin forest or onto a secondary forest fallow, hopefully one with 17-21 years regrowth (see testimony on page 38).

   C. Is the decrease in crop productivity the reason for the constant moving of cultivation areas?

   Yes, and that decrease in productivity is brought about by the soil fertility decline which allows for better weed competition after only two crops on these marginal soils (see testimony on page 38).

Amazon Basin Research

2. In your testimony you state that the site selected in Peru was representative of the soil, climate, and socioeconomic conditions faced by small farms in Colombia and Brazil as well as in Peru.

   A. Does this mean that the research results could be applied to all these countries? Could it be applied to any other countries?

   Very definitely. In fact, it has been and is being successfully applied through adaptive research trials in San Ignacio, Bolivia and Manaus, Brazil (see testimony on page 39). It will be applied by a cooperative University of Hawaii/North Carolina State Universith/Indonesian government effort in the transmigration areas of Sumatra beginning in January, 1983 (see testimony on page 46). The Peruvian government has requested our help in applying the Yurimaguas technology to other jungle areas in Peru. Requests for adaptive technology transfer to humid tropical regions of Mexico, Guatemala, Ecuador, Guyana have also been received. There is certainly potential for extrapolation also to the humid tropical areas of Africa.

   B. What role do sociological factors play in the success or failure of research projects such as this one?

   They play an extremely important role. We have been fortunate in that the sociological and economic factors in Peru have been favorable. However, all small farmers are businessmen and businesswomen. If they become convinced that the improved technologies can be productive for them at relatively low risk then they will adopt the practices. We have seen this happen over many areas in the humid tropics.

Fertilizer Use

3. One of the major technologies used in your research project was the use of fertilizer to maintain continuous cultivation.

    A. Are there different types of fertilizers, other than commercial chemical fertilizer, that could be used by the farmers?

    Yes (see testimony on page 44), but again there are two disadvantages. One, the 10 tons of compost per hectare does not supply enough calcium and magnesium to neutralize the acidity of the soil to produce good crop growth nor enough potassium to meet crop demands. Secondly, the farmers themselves reject the required 10 tons of compost due to the high labor cost in favor of several 100-pound sacks of fertilizer.

    The use of acid-tolerant varieties of rice, cowpeas and perhaps peanuts means that only 1/2 ton of lime need be used where 3 or 4 have been required for the non-tolerant varieties. Thus, by modifying the crop to fit the soil conditions rather than the other way around, lime and perhaps fertilizer inputs can be reduced, but not eliminated (see testimony on pages 43-44).

    B. Isn't one of the disadvantages of this project that it encourages dependence on commercial fertilizers?

    We are deluding ourselves and the people of the developing world if we think for one minute that crops can be produced continuously on these marginal soils without commercial fertilizer inputs. Even the very fertile soils of our Midwest require fertilizer inputs and they are starting at a much higher fertility level than these marginal soils will ever attain. Certainly a reduction in lime and fertilizer inputs is possible; we are researching ways to reduce these inputs (see answer to 3.A.), but we will never be able to completely eliminate them. Nature was not designed to allow continual harvests without inputs.

Research Results

4. Your research results show that 21 consecutive crops can be grown from the same plot of land that normally grew only one or two crops. Fertilizer management was a major factor in the success.

   A. What impact could this have on the food production in the Amazon Basin?

   A large potential impact. It means that the small farmers can economically increase their food production while at the same time reducing the quantity of rainforest being cleared. Implications are apparent and far-reaching (see testimony on pp. 42-43, 45-46).

   B. What will be the long-term impact on the soil and ecology?

   Favorable. In fact, this continuous cropping technology enables governments which share the common heritage of the Amazon rainforest to have the alternative to vast continued clearing and therefore, should result in less clearing while increasing food production (see testimony on pp. 45-46). Over 10 years of continuous cropping the marginal soils at Yurimaguas has shown an improvement in both soil chemical and physical characteristics.

   C. Is this technology usable by the local farmers without dependence on outside materials?

   No. Again (see answer to 3.B.), we are performing a disservice to the people of the world if we think that there will be high crop yields without judicious lime and fertilizer inputs.

Economic Impact

5. Your research results indicate that for every one dollar invested a net return of $2.91 is obtained.

   A. When the research plots are scaled-up to large farms, will the profit ratio remain roughly the same?

   Yes, or even better. Those results were from the experiment station trials. When data obtained from the farmers themselves with the improved technology were used, the marginal rate of return was 612%. Computer-assisted economic analysis showed that a traditional seven-member farm family with their constraints of labor, nutritional intake, and capital could successfully implement, manage and realize this return on a 3-1/2 acre field. As long as the market remains fairly elastic, and this is projected for the area, such returns are accurate.

B. Is the cost of labor included in the total cost?

Yes, and only family labor was included due to the fact that if everyone is planting, managing, and harvesting at approximately the same times, then labor is a major constraint. In fact, contrary to popular opinion here in the U. S., labor is one of the main constraints faced by small farmers in the humid tropics.

C. Does this farming method require a significant capital investment to start? Can poor farmers effectively utilize this method with almost no investment?

This farming method does not require a significant capital investment to start. The average small farm family in the Yurimaguas area has a net income of U. S.$750. Economic analysis showed that a capital investment of $150 from the farmer plus $150 from the bank at (68% APR) produced a net return for the farm family of nearly $2800 on a 3-1/2 acre field. Poor farmers are effectively utilizing this technology with this small investment.

Farmer Acceptance

6. In your statement, you indicate that small farm holders are beginning to accept this alternative cropping system.

A. Why is there resistance to this cropping system by the farmers?

There is not resistance to this cropping system by the farmers. More farmers are wanting to use it than we, the extension service and the bank agronomists can effectively backstop. The word "beginning" was used to indicate just that--a beginning, but not resistance.

B. What programs are used to encourage farmer acceptance?

The on-farm and on-school extrapolation trials (see testimony on pp. 42-43). The Peruvian Ministry of Agriculture is increasing its extension component in the Yurimaguas and other jungle areas to more adequately respond to farmer demands for this alternative technology.

AID Programs

7. Having worked with AID and international organizations for many years,

A. How would you evaluate AID's agriculture technology program?

Very well, and especially now with the tremendous agricultural capability offered by Drs. Brady, Bertrand, Robbins, O'Donnell, Walker, Malcolm, Gill and others of the S & T Bureau. Administrator McPherson has done an outstanding job in bringing in and keeping excellent agricultural development specialists. What is needed desperately are many more capable agriculturists in the field at the Mission level. Many of these need to be posted in the field rather than the USAID office in the capital city where they have become, in spite of their capabilities, merely paper pushers responding to a cable mentality. They need to have hands-on research and extension experience.

This is one of the great advantages of the Title XII Collaborative Research Support Programs such as TROPSOILS, in that top-notch U. S. university scientists with international agricultural experience are posted in the field with developing country counterparts to address these pressing research and extension issues.

B. What additional research should be supported by AID that presently is not being done?

Resources, such as soil and water management, which cut across commodity lines, should receive increased emphasis and funding. Most of the international agricultural research centers (IARC's) deal with a specific commodity or commodities and, with few exceptions, do not have the personnel to adequately address the resource issues. This is one reason that the Soil Management CRSP (now known as TROPSOILS) is tying in so closely with several of the IARC's. There is a tremendous need for this soil and water management work in Africa, but insufficient funds to address it adequately.

However, not even TROPSOILS is able to address all of the important soil management issues. Case in point is the fact that the desperately-needed research on management of steepland soils for crop production and erosion control had to be dropped from TROPSOILS because funding allocations were only 60% of those requested. This steeplands research area should receive extremely high priority when funds are shifted or new ones become available. Once the soil resource base has eroded away, the small farmers of the steeplands have nothing left--and this is happening.

Increased research in biological nitrogen fixation is needed. The most expensive commercial fertilizer input is nitrogen. Let's key on nitrogen via both research in symbiotic and asymbiotic N-fixation work which could have a major impact not only in the developing countries, but the developed countries as well.

More work on crop species and varieties adapted to marginal soil conditions is also needed (see answer to question 3.A).

We also need to recognize the fact that natural resource and ecological stresses produce economic and eventually political stresses which become threats to democratically-elected governments in the developing (and even developed) world. Just as our military has a well-financed training program for LDC young military leaders who are projected to be the future military and political leaders of those developing countries, we need a similar high priority training program for young LDC scientists whom we project to be the future agricultural and political leaders of those developing countries. Training needs to center on not only agricultural sciences and economics, but also on management and administration.

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FERTILIZER MANAGEMENT FOR CONTINUOUS CROP PRODUCTION ON ULTISOLS OF THE AMAZON JUNGLE BASIN OF PERU

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ABSTRACT

Twenty-one consecutive crops have been harvested from the same plot of fine-loamy, siliceous, isohyperthermic Typic Paleudult, from which normally only one or two crops are grown before soil reverts to secondary jungle vegetation in the native migratory agricultural system. Judicious fertilizer and lime amendments, as dictated by soil test analysis, when applied to various crop rotations proved to be the key component of managing these soils. Total annual yields of the judiciously fertilized three crop rotation of rice-corn-soybean or rice-peanut-soybean averaged 7.8 tons grain/ha over the eight-year cropping period as compared with 0.1 tons/ha on the traditionally managed check plots. Results indicated the lime and fertilizer amendments to be not only agronomically productive, but economically feasible as well.

INTRODUCTION

Shifting cultivation is accepted as being one of the primary causes for the clearing of the Amazon Basin rainforest (Denevan, 1973). Should an alternative system for continuous cropping be developed, made available to and accepted by shifting cultivators, then it is possible that, in at least portions of the Amazon Basin, shifting cultivation could be replaced by continuous cultivation. Such a development would help increase food production for the people of the Basin, while at the same time help to preserve the ecological integrity of much of the yet undistrubed rainforest of that Basin.

Since 1971 North Carolina State University's Tropical Soils Research Program under U.S. Agency for International Development funding and in cooperation with the Peruvian Ministry of Agriculture's National Agricultural Research and Promotion Institute has been developing soil management technologies for changing shifting cultivation to continuous cultivation on the acid, infertile soils which represent 75% of the Amazon Basin.

MATERIALS AND METHODS

Soils and crop yields on experiment station

The field research from 1971 to present has been conducted on a level, fine-loamy, siliceous, isohyperthermic Typic Paleudult (Table 1) at Yurimaguas, Peru's last large fluvial port on the Amazon River headwaters (5°45'S, 76°05'W, 184 meters above sea level). Mean annual temperature and rainfall, respectively, are 26°C and 2200 mm. Site was selected after a thorough study of soil properties of the Amazon Basin of Peru (Sanchez & Buol, 1974), Colombia and Brazil and is considered representative of soil, climate and many socioeconomic conditions faced by small farmers migrating from densely populated areas into the Amazon Basin.

Table 1

Selected soil properties of Typic Paleudult (Yurimaguas series) on which field research was conducted in Amazon Basin of Peru (Source: Seubert et al 1977).

Horizon depth	Clay	Sand	Org. C	pH	Exchangeable Al	Exchangeable Ca	Exchangeable Mg	Exchangeable K	Effective CEC	Al Sat'n
	%	%	%	H_2O	meq/100 cc	meq/100 cc	meq/100 cc	meq/100 cc	meq/100 cc	%
0-5	6	80	1.3	3.8	2.05	0.84	0.37	0.20	3.49	59
5-13	10	70	0.8	3.7	2.63	0.05	0.03	0.04	2.76	95
13-43	15	61	0.4	3.9	3.11	0.05	0.03	0.03	3.24	96
43-77	17	57	0.3	4.0	3.12	0.03	0.01	0.02	3.20	98
77-140	25	51	0.2	4.1	4.48	0.03	0.01	0.03	4.58	98
140-200	24	54	0.2	4.4	3.80	0.06	0.03	0.04	3.94	96

The fertilizer value of the ash from the traditional burn as practiced by shifting cultivators was determined and soil nutrient dynamics and crop yields with and without lime and fertilizer over time of cropping were monitored. Various rotations of three crops per year were employed; presented herein will be the upland rice-corn-soybean rotation.

On-farm extrapolation trials

In 1978 it was felt that the improved continuous cropping systems had been developed sufficiently to begin extrapolating them from the research station to small farmers of the area. Eleven small farm holders in an 80 km radius from Yurimaguas participated in the 1978-1979 trials. Cooperating farmers compared their traditional management systems on soils similar to (Typic and Aquic Paleudults and Tropudults) and more fertile than (Typic Tropudalfs and Vertic Eutropepts) those of the experiment station with two improved systems developed on the experiment station; one was without lime and fertilizer, the other with 1 ton lime $CaCO_3$-equivalent per year, 60 kg N/ha for rice and corn only, 35 kg P/ha/crop, 66 kg K/ha/crop and 22 kg Mg/ha/crop. Economic analysis of their results was performed.

RESULTS AND DISCUSSION

Fertilizer value of ash

As the fertilizer value of the ash (Table 2) was revealed to be one of the reasons for improved crop yield on slashed and burned land as compared with bulldozer-cleared land (Seubert et al 1977), plots on the station were cleared by slash and burn to make use of this nutrient value.

Table 2

Nutrient content of the ash and partially burned material produced by slashing and burning a 17-year old forest fallow on an Ultisol in Yurimaguas, Peru (Source: Seubert et al 1977).

	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
Content, kg/ha	67	6	38	75	16	7.6	7.3	0.3	0.3

Crop yields with adequate lime and fertilizer

A rotation of upland rice-corn-soybean when properly limed and fertilized produced 21 consecutive crops averaging 7.8 tons grain/ha/yr over an eight-year period (Fig. 1). Without lime and fertilizer, yields declined to zero with the third consecutive crop.

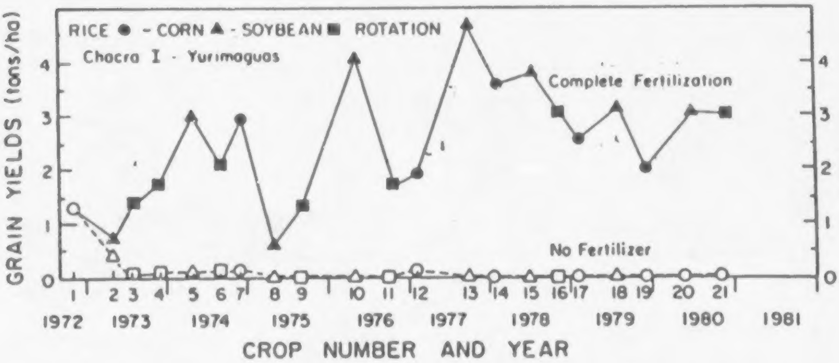

Fig. 1. Yield record of a continuously cultivated plot in an Ultisol of Yurimaguas, Peru with and without judicious use of lime and fertilizer (Adapted from Sanchez et al 1982).

Lime and fertilizer requirements for this or the upland rice-peanut-soybean rotation on the soil researched were determined to be 3 tons lime as $CaCO_3$-equivalent/ha/3 years, 80-100 kg N/ha for rice and corn, 25 kg P/ha/yr, 100 kg K/ha/yr, 25 kg Mg/ha/yr unless dolomite is lime source, 1 kg/ha/yr or two years of Cu, Zn and B, and 20 g Mo/ha mixed with legume seed during inoculation. These results indicate that such moderate liming and fertilization can continuously sustain moderately high yields of these annual crops on the level sandy loam Ultisols of the Amazon Basin.

Economic evaluation

Not only were these systems agronomically feasible, but they were found to be economically productive as well. A net return of U.S. $2.91 per U.S. $1.00 invested in lime and fertilizer at the 1977 Yurimaguas prices, including transportation costs, was realized for the upland rice-peanut-soybean rotation. Projected annual family incomes from using the "Yurimaguas technology" on 1.5-2.0 hectare farms ranged from U.S. $714 to $4,180 when upland rice, maize, peanut, soybean and cassava were the crops grown (North Carolina State University, 1980).

Effects on soil properties

The issue of cultivation in the humid tropics resulting in soil degradation is a concern in the literature (Goodland & Irwin, 1975). However, the results of this study indicate that soil chemical properties improved with intensively managed, appropriately limed and fertilized continuous corn production systems (Table 3).

Table 3. Changes in topsoil (0-15 cm) chemical properties after nearly eight years of continuous production of 20 crops of upland rice, corn, and soybean with adequate lime and fertilizer at Yurimaguas, Peru (Source: Sanchez et al 1982).

			Exchangeable				Eff.	Al	Available		
Time	pH	O.M.	Al	Ca	Mg	K	CEC	Sat'n	P	Zn	Cu
	H_2O	%	----- meq/100 cc -----					%	--- ppm ---		
Before clearing	4.0	2.13	2.27	0.26	0.15	0.10	2.78	82	5	1.5*	0.9*
After 94 months	5.7	1.55	0.06	4.98	0.35	0.11	5.51	1	39	3.5	5.2

* 30 months after clearing

After almost eight years of properly liming and fertilizing 20 consecutive crops, the topsoil pH had increased from a very acid 4.0 before clearing to a favorable 5.7. The organic matter decrease of 27% occurred mostly in the first year of cropping. Liming decreased Al saturation on the exchange sites from a toxic 82% to a negligible 1% and increased exchangeable Ca levels nearly twentyfold. Exchangeable Mg levels doubled over the 94 months, but levels were observed to fluctuate with time. Lack of increase in exchangeable K levels in spite of K fertilizer applications suggested rapid utilization by crops and perhaps leaching to the subsoil. The near doubling of the CEC was a boon to this soil and was probably a consequence of the pH-dependent charge characteristics of the kaolinite clay-iron oxide mixture. Phosphorus applications increased available P from below the critical level of 10 ppm to well above it. As Zn and Cu were also applied as fertilizers, their levels increased above the respective critical levels of 3 and 1 ppm. However, as no Mn was applied and available Mn levels declined to less than the critical level of 5 ppm, a Mn deficiency was suspected; current research is looking at that situation. Available Fe levels remained considerably above the critical level of 20 ppm. Overall, these changes are indicative of improvement in the topsoil's chemical properties and are reflected by the good cumulative grain production of 7.8 tons/ha/yr.

No unfavorable changes in soil physical properties have been detected thus far (North Carolina State University, 1980) because of the yearly protection that three well-fertilized crops with a complete canopy provide against rain impact on the soil. Conversely, severe surface soil compaction was rampant in the non-limed and non-fertilized continuously cultivated crops because of the incomplete canopy developed. Thus, the healthy fertilized crops produced a good complete canopy which resulted in less surface soil compaction and less potential runoff.

Farmer acceptance

The true test of any improved technology for continuous cropping in the Amazon Basin is its acceptance and utilization by the target group -- the shifting cultivators. The first year's results revealted that each of the eleven cooperating farmers produced a cumulative corn-peanut-corn grain yield ranging from 7.5 to 11.4 tons/ha with the improved system using lime and fertilizer, while yields from the same rotation under their traditional system ranged from 3.5 to 5.3 tons/ha (North Carolina State University, 1980).

Soil analysis after three consecutive crops in the traditional system revealed nutrient depletion due to crop removal and loss of ash-liming effect. In all farms, soils had become more deficient in P, more acidic with exchangeable Al increasing and Ca and Mg decreasing. This nutrient depletion was reflected in declining corn yields in the corn-peanut-corn rotation. As the nutrient depletion become more severe in the second year of the trials, yields declined even further in the traditional system while they were maintained in the improved system with lime and fertilizer.

Economic analysis using limited resources restricted capital, labor and work output of the small holder farm family to all possible levels and combinations. This analysis revealed that the limed and fertilized corn-peanut-corn rotation on a 1.45 hectare farm using U.S. $90 as owned capital, another U.S. $90 as borrowed capital (at 68% annual interest rate) and a seven-member small holder farm family model as the labor pool could realize a net farm income of U.S. $2,797 at current rates of exchange (North Carolina State University 1980). That net income is considerably greater than the current small holder farm net income of U.S. $750 in the Yurimaguas area and than the U.S. $1,500 annual net income of the top 25% of the families in Lima's slums.

As a result of these extrapolation research trials managed by the small holders themselves, the small holders in the region have available to them and are beginning to accept alternative cropping systems which could allow them to permanently and economically farm their soils normally subjected to shifting cultivation.

Concluding statements

It would be unwise to infer that the continuous crop production technologies described herein are directly applicable to all acid, infertile soils (Oxisols and Ultisols) of the Amazon Basin. Our work has concentrated on level Ultisols in the upper Amazon Basin, thereby avoiding the erosion hazards of cultivating undulating lands. Any contemplated use of the "Yurimaguas technology" to other areas must be preceded by adaptive agronomic research and socio-economic interpretations based on site specificity and local and national policies and priorities. Also, second and third generation problems with nutrient balance, micronutrient deficiencies, diseases, insects and weeds must be dealt with through continuing research, as is being done by the NCSU/INIPA team in Yurimaguas.

Once those issues have been addressed, the potential of the "Yurimaguas technology" is that the indigenous people, settlers and governments in the Amazon Basin will have available an agronomically, economically, and ecologically sound alternative to shifting cultivation. Thus, it is likely that some areas of the humid tropics could make a major contribution to increasing world food production in the next decades (Sanchez 1977, Nicholaides 1979).

ACKNOWLEDGEMENTS

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REFERENCES

Denevan, W. M. (1973) Development and the imminent demise of the Amazon rain forest. *The Professional Geographer* 25, 130-135.

Goodland, R. J. A.; Irwin, H. S. (1975) *Amazon Jungle: Green Hell to Red Desert?* Elsevier. Amsterdam. 155 pp.

Nicholaides, J. J. III (1979) Crop production systems on acid soils in humid tropical America. Chpt. 16. pp 243-277. *In* W. Thorne and M. Thorne (eds.) *Soil, Water and Crop Production*. AVI Press, Westport, Conn.

North Carolina State University (1980) *Tropical Soils Research Program Report for 1978-1979*. Department of Soil Science, Raleigh, N.C. 284 pp.

Sanchez, P. A. (1977) Advances in the management of Oxisols and Ultisols in tropical South America. pp. 535-566. *Proceedings of the International Seminar on Soil Environment and Fertility Management in Intensive Agriculture*. Society of Science and Manure. Japan.

Sanchez, P.A.; Buol, S. W. (1974) Properties of some soils of the upper Amazon Basin of Peru. *Soil Science Society of America Proceedings* 38, 117-121.

Sanchez, P. A.; Buol, S. W. (1975) Soils of the tropics and the world food crisis. *Science* 180, 598-603.

Sanchez, P. A.; Bandy, D. E.; Villachica, J. H.; Nicholaides, J. J. (1982) Amazon Basin soils: Management for continuous crop production. *Science* 216, 821-827.

Seubert, C. E.; Sanchez, P. A.; Valverde, C. S. (1977) Effects of land clearing methods on soils properties of an Ultisol and crop performance in the Amazon jungle of Peru. *Tropical Agriculture* 54, 307-321.

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SCIENCE

Amazon Basin Soils: Management for Continuous Crop Production

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Amazon Basin Soils: Management for Continuous Crop Production

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Summary. Technology has been developed which permits continuous production of annual crops in some of the acid, infertile soils of the Amazon Basin. Studies in Yurimaguas, Peru, show that three grain crops can be produced annually with appropriate fertilizer inputs. Twenty-one crops have been harvested during the past 8½ years in the same field, with an average annual production of 7.8 tons of grain per hectare. Soil properties are improving with continuous cultivation. The technology has been validated by local farmers, who normally practice shifting cultivation. Economic interpretations indicate large increases in annual family farm income and a high return on the investment of chemical inputs. Other promising land use alternatives include low-input crop production systems, paddy rice production in fertile alluvial soils, and pastures or agroforestry in rolling areas. Stable, continuous food crop production is an attractive alternative to shifting cultivation in humid tropical regions experiencing severe demographic pressures. For each hectare of land managed in a highly productive manner, there may be less need for clearing additional tropical forests to meet food demands.

The humid tropics, which cover about 10 percent of the world's land surface, is a crucial ecosystem because of its agricultural potential and the possible ecological consequences of its deforestation (*1–4*). Projections of world food supply and demand indicate that an additional 200 million hectares must be put into cultivation before the turn of the century just to maintain the present, largely inadequate, level of food production in the developing world (*5*). This amount of land, which exceeds the harvested cropland in the United States, is needed despite the expected increase in yields in areas now under cultivation.

The use of high-yielding crop varieties, fertilization, and irrigation in fertile soils resulted in impressive increases in food production in the tropics during the 1970's (*6*). It is widely acknowledged that future efforts to increase world food production must be directed toward the marginal lands of the developing world, where, because of severe climatic and soil constraints, preservation of the land resource base is a major consideration (*7*).

Several land resource studies indicate that the greatest potential for agricultural expansion into virgin or underutilized lands lies in the humid tropics and acid savannas (*1, 8*). The humid tropics is that part of the world with a variation of less than 5°C in mean monthly air temperature between the three warmest and three coldest months, no more than a 4-month period in which potential evapotranspiration exceeds precipitation, and native forest vegetation. This ecological region occupies about 1500 million hectares, of which at least half is considered potentially arable or grazeable (*1, 8, 9*). The acid savannas are areas with a similar temperature regime, tropical savanna vegetation, a dry season of 4 to 6 months, and predominantly acid soils. They occupy about 300 million hectares, of which 150 million are potentially arable or grazeable (*9*).

Large-scale expansion of agricultural land in other ecosystems is hampered by low temperatures, lack of water, severe erosion, or already intensive land use. The humid tropics and acid savannas are blessed with temperatures, rainfall, and topography which favor agricultural development. The main factors limiting such development are low soil fertility, a limited transportation and marketing infrastructure, and lack of appropriate soil management technology. Agricultural development is progressing rapidly in those acid savanna regions where transportation and marketing are being improved and soil management technology is being applied (*10*). Ecologically, the acid savannas are considered less fragile than the humid tropics (*11*).

Estimates of the rate of conversion of tropical forests into agricultural land vary widely; so do estimates of the environmental consequences associated with such conversions (*3, 4, 12, 13*). Despite the divergence of opinion, one basic premise runs through many reports on this topic: that it is not possible to continuously cultivate the acid, infertile soils of the humid tropics. The red or yellowish color of most of these soils, indicative of the presence of iron oxides, has led to the generalization that when cleared and cultivated they will turn into laterite, a red desert, or a compacted soil surface resembling the Sahel (*12, 14*).

More than 50 years ago, C. F. Marbut, the father of American soil science, traveled in the Amazon region and published an article (*15*) stating that most of the soils he observed were strikingly similar to the main soils of southeastern United States. During the past decade, major soil mapping efforts and soil management research have confirmed Marbut's statements and provided a quantitative assessment of the properties and potential of soils in the Amazon Basin.

Soils of the Amazon Basin

Soil taxonomy is similar to plant taxonomy in the sense that only properties that can be measured are considered (*16*). The world's soils have been mapped with a common soil legend at a scale of 1:5 million (*17*). This legend is readily converted into soil taxonomy units. Detailed surveys have been conducted in parts of the humid tropics with satellite and radar imagery—particularly in the Amazon. This region has been mapped at a scale of 1:1 million. A synthesis of the land resources of tropical America is now available in computer-retrievable form from the International Center for Tropical Agriculture (CIAT) (*18*). This synthesis, together with other data, makes it possible to accurately characterize the soils of the Amazon region (*19*).

Some 75 percent of the Amazon Basin is dominated by acid, infertile soils classified as Oxisols and Ultisols (Table 1). They are deep, well-drained, red or yel-

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Table 1. General distribution, by topography, of major soils in the Amazon Basin (*19*).

Soil grouping	Millions of hectares				
	Flat, poorly drained	Well-drained			Total (percent)
		Slope 0 to 8 percent	Slope 8 to 30 percent	Slope > 30 percent	
Acid, infertile soils (Oxisols and Ultisols)	43	207	88	23	361 (75)
Poorly drained alluvial soils (Aquepts, Aquents, Gleysols)	56	13	1		70 (14)
Moderately fertile, well-drained soils (Alfisols, Mollisols, Vertisols, Tropepts, Fluvents)	0	17	13	7	37 (8)
Very infertile, sandy soils (Spodosols, Psamments, Podzols)	10	5	1		16 (3)
Total	109	242	103	30	484

lowish soils with favorable physical properties, but they are very acid and deficient in plant nutrients (*20*). Next in abundance (14 percent) are the poorly drained alluvial soils, which are located mainly in flood plains or inland palm swamps. About 8 percent of the Amazon Basin has well-drained soils with moderate to high fertility. Although only 3 percent is covered by the extremely acid and infertile sandy soils known as Tropical Podzols, Spodosols, and Psamments, research on such soils has received widespread attention (*21*). Conclusions based on the extreme paucity of nutrients typical of these soils cannot be generalized to the entire Amazon.

About half of the Amazon Basin consists of well-drained landscapes with slopes of less than 8 percent (Table 1). The other half has poor drainage or slope limitations.

Most of the constraints imposed by Amazon soils on agricultural development are chemical, rather than physical, in nature (Table 2) (*22*). Phosphorus deficiency is found in 90 percent of the soils; the effects of this deficiency depend on which crops are grown. Fortunately, only 16 percent of the Amazon has soils capable of fixing large quantities of phosphorus into relatively insoluble forms. Although most Amazon soils will require phosphorous fertilization, the quantities required are not likely to be as high as in the acid savannas, where high phosphorus fixation is a major problem (*10*).

Aluminum toxicity, the main cause of poor plant growth in acid soils, affects about three-fourths of the region. Low potassium reserves are also widespread. Poor drainage and flooding affect one-fourth of the region (this area includes flood plains and inland swamps).

About 15 percent of the Amazon has effective cation exchange capacity (CEC) values below 4 milliequivalents per 100 grams. A low CEC indicates that there are few negative charges in the soil capable of retaining nutrient cations such as calcium, magnesium, and potassium. Consequently, even when large quantities of such nutrients are applied, they can be rapidly lost by leaching, particularly in well-drained soils. Also, since soils with low CEC values are poorly buffered, fertilizer and lime applications may affect the behavior of other soil properties.

About 92 percent of the Amazon has soils that are relatively secure from severe erosion. This is partly due to the level to gentle slopes found in 82 percent of the region (*19*) and partly to the favorable structure of many Oxisols and Ultisols. The highly erodible soils (39 million hectares) occur mainly on steep slopes. Such soils are susceptible to erosion unless protected by a plant canopy. Overall, the Amazon soils are less erodible than soils in other major ecological zones, such as the semiarid tropics.

This is not to imply that erosion is a trivial issue in the Amazon. All soils can be eroded through mismanagement, and sheet erosion can occur in nearly level, well-drained Oxisols and Ultisols if they are not protected by vegetation. This seldom happens in tropical forested regions, because when crops or pastures fail, weeds and secondary forest regrowth usually produce a plant canopy rapidly. Sheet erosion and gullying along cattle trails in poorly managed, overgrazed pastures, however, are increasing. Most of the obvious gully erosion involves roads, building sites, and urban sewage or drainage systems.

Only 4 percent of the Amazon is subject to laterite formation (Table 2). This percentage reflects the 21 million hectares of soils (Plinthaquox, Plinthaquults, and Plinthudults) with soft plinthite in the subsoil. This point deserves emphasis, given the widespread belief that Amazon soils, once cleared, are irreversibly transformed into hardened plinthite or laterite. These three soil groups are the only ones in which this phenomenon can occur, but because the soft plinthite is in the subsoil, the topsoil has to be removed by erosion before hardening to laterite can take place. Since these soils occur mainly on flat, poorly drained landscapes, erosion is not likely to be extensive.

Hardened laterite outcrops are found in geomorphically predictable positions in areas geologically affected by Guayanan and Brazilian shields, and sometimes are mixed with soil materials. They are in reality an asset to development because they provide excellent road-building materials at low cost. The lack of laterite in upper Amazon areas not affected by the Precambrian shields is a constraint to road building.

Only about 6 percent of the Amazon has soils with no major limitations to agriculture. Nevertheless, they represent a total of 32 million hectares. They are classified mainly as Alfisols, Mollisols, Vertisols, and well-drained alluvial soils, and where they occur permanent agriculture has a very good chance of success.

Need for Continuous Cultivation Technology

Although food crop production should logically concentrate first on the more fertile soils of a region, the limited extent of such soils in the Amazon and the considerable flooding hazard associated with many of them indicate that major increases in food crop production must be based on the dominant Oxisols and Ultisols. At present, shifting cultivation is almost the only food crop production system in Oxisol and Ultisol regions of the Amazon. Farmers slash and burn a patch of the forest and harvest one or two crops before soil fertility, derived almost entirely from the ash of the burned vegetation, is depleted and weed control problems force them to abandon the land. Although shifting cultivation in its traditional form is ecologically sound

(*23*), it is a guarantee of perpetual poverty for those who practice it (*24*). Increased population pressures in several parts of the Amazon have resulted in a shortening of the periods during which the land is left fallow, precluding restoration of the soil's fertility and turning an ecologically sound farming system into an unproductive, ecologically damaging one. This is already evident in much of the forested zone of West Africa, where a rapid increase in population density has led to the conversion of most of the virgin forest into highly unstable shifting agriculture (*3*, *25*).

Table 2. Principal limitations of soils in the Amazon Basin under native vegetation (*19*).

Problem*	Million hectares	Percentage of Amazon Basin
Phosphorus deficiency	436	90
Aluminum toxicity	352	73
Low potassium reserves	271	56
Poor drainage, flooding	116	24
High phosphorus fixation	77	16
Low cation exchange capacity	71	15
High erodibility	39	8
No major limitations	32	6
Steep slopes (> 30 percent)	30	6
Laterite formation if subsoil exposed	21	4
Shallow (< 50 centimeters deep)	3	

*Nitrogen, sulfur, magnesium, and zinc deficiencies and temporary drought stress are widespread, but cannot be quantified with available data.

Research Program in Yurimaguas

In 1971 North Carolina State University, in cooperation with the predecessor agencies of the Instituto Nacional de Investigación y Promoción Agraria, initiated the Tropical Soils Research Program in Yurimaguas, Peru, to determine whether continuous cultivation of basic food crops is possible in acid, infertile soils of the Amazon Basin (*26*). Yurimaguas, the westernmost large fluvial port of the Amazon headwaters (5°45'S, 76°05'W; 184 meters above sea level) has a mean annual temperature of 26°C and mean annual rainfall of 2100 millimeters. The rainfall is well distributed throughout the year, with 3 months averaging 100 millimeters and the rest about 200 millimeters. The native vegetation is tropical rainforest. The principal soil of the experiment station is a flat, well-drained Ultisol, with a sandy loam surface over a clay loam subsoil. It is very acid (*p*H 4.0), high in aluminum, deficient in phosphorus, potassium, and most other nutrients, and low in CEC (*26*). These conditions are typical of much of the Amazon.

The choice of land clearing method is the first and probably the most crucial step affecting the productivity of farming in the humid tropics. Field trials confirmed that methods involving slash-and-burn are superior to mechanical removal of vegetation. The ash produced by burning adds nutrients to the soil, while bulldozing often causes soil compaction and displaces topsoil, depositing it outside the field (*27*).

After identifying the desirability of traditional slash-and-burn land clearing, researchers then focused on determining the most appropriate crops and crop rotations, fertilization needs, and changes in soil properties with cultivation. Several basic food crops have been studied, including upland rice, corn, cassava, plantains, soybeans, peanuts, sweet potatoes, cowpeas, and winged beans, either as monocultures or in combinations (*26*). The most promising results so far have been obtained by growing three crops a year as rotations of upland rice, corn, and soybeans or upland rice, peanuts, and soybeans. These rotations are adapted to the rainfall pattern and keep the ground covered most of the year. Continuous monoculture of the same crops, however, did not produce sustained yields because of a buildup of pathogens.

Figure 1 shows the grain yields of 21 consecutive crops harvested from the same field since it was cleared by slash-and-burn in October 1972 and cultivated with the rice, corn, and soybean rotation. Without fertilization, yields dropped to zero after the third consecutive crop. With complete fertilization, the long-term average of this rotation, which was replicated in three fields, was 7.8 tons of grain per hectare per year.

The upland rice, peanut, and soybean rotation was also successful. It may be more appropriate because in this environment peanuts have a higher yield potential than corn. Corn suffered from

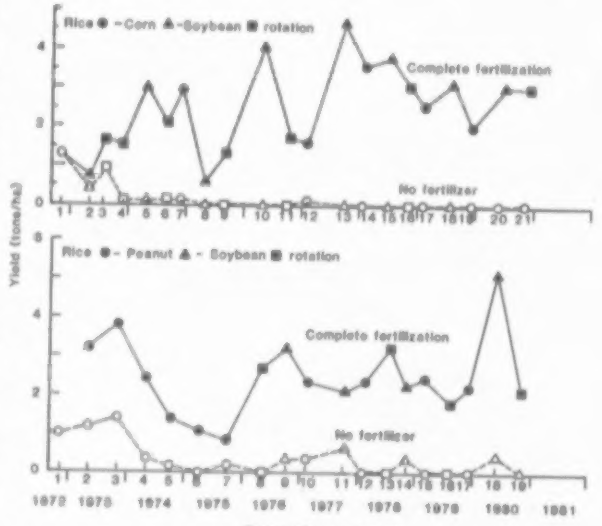


Fig. 1. Yield record for two continuously cultivated plots at Yurimaguas, with and without fertilization (*26*).

the low solar radiation and high night temperatures, and it was subjected to more insect attacks than the other three crops. Figure 2 shows the long-term average yields of 88 harvests of these four crops with and without adequate fertilization during the past 8 years. Upland rice, soybean, and peanut yields are excellent; corn yields are moderate. Figure 2 also indicates a reasonable yield stability for the four crops. These results show that continuous production can be achieved in the Amazon with adequate fertilization.

Nutrient Dynamics: The Key Factor

The term "adequate fertilization" was not arrived at lightly. It took about 4 years to gather conclusive data on the changes in soil properties that occurred after clearing and burning a 17-year-old secondary forest and growing annual crops continuously. The nutrient dynamics were monitored by sampling soils after each harvest and analyzing for *p*H, organic carbon, total nitrogen, exchangeable aluminum, potassium, calcium, magnesium, effective CEC, and available phosphorus, zinc, copper, iron, and manganese. Sulfur, boron, and molybdenum levels were determined periodically by plant analysis. Such records were kept for three fields cleared in 1972, 1973, and 1974. The fields were given complete, intermediate, or no fertilization, and there were four replications. The timing of the appearance of soil fertility limitations and the intensity of their expression varied among the fields, even though they were near each other, were on the same soil mapping unit, and had the same vegetation before clearing. The intensity of the fire during clearing is considered a factor contributing to this variability.

Table 3. Fertilizer requirements for continuous cultivation of annual rotations of rice, corn, and soybeans or rice, peanuts, and soybeans on an acid Ultisol in Yurimaguas (26).

Input*	Amount per hectare	Frequency
Lime	3 tons	Once every 3 years
Nitrogen	80 to 100 kilograms N	Corn and rice only
Phosphorus	25 kilograms P	Every crop
Potassium	80 to 100 kilograms K	Every crop, split application
Magnesium	25 kilograms Mg	Every crop (unless dolomitic lime is used)
Copper	1 kilogram Cu	Once a year or once every 2 years
Zinc	1 kilogram Zn	Once a year or once every 2 years
Boron	1 kilogram B	Once a year
Molybdenum	20 grams Mo	Mixed with legume seeds only

*Calcium and sulfur requirements are satisfied by lime, simple superphosphate, and magnesium, copper, and zinc carriers.

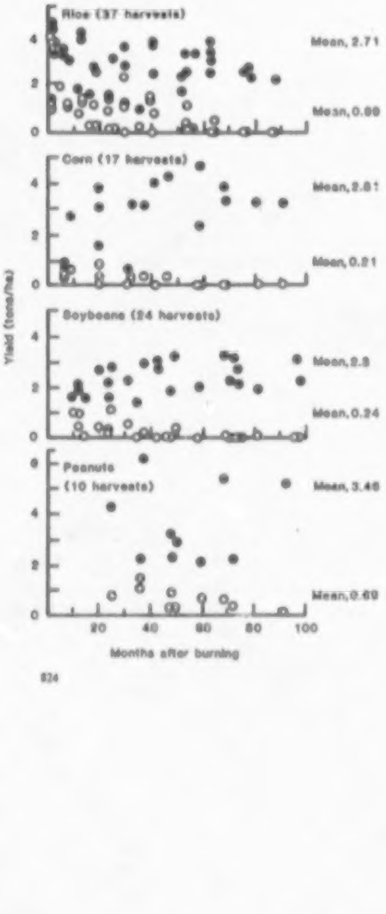


Fig. 2. Crop yields at Yurimaguas (1972 to 1980) with complete fertilization (●) and with no fertilization (○).

Ash from the burning produced a temporary increase in *p*H, available nitrogen, phosphorus, potassium, calcium, magnesium, and some micronutrients and a decrease in exchangeable aluminum to below toxic levels. As a result, upland rice, the first crop planted, did not suffer from soil fertility limitations. By about 8 months after clearing, however, the levels of available nitrogen and potassium were reduced such that crops were affected adversely; in addition, sporadic sulfur, copper, and boron deficiencies appeared. Organic matter in the topsoil decreased sharply during the first year, with a decomposition rate of 25 percent per year. Organic matter reached a new equilibrium level starting with the second year. The rapid organic matter decomposition probably released many H^+ ions that acidified the soil and increased exchangeable aluminum to toxic levels, reversing the liming effect of the ash.

Phosphorus and magnesium became deficient during the second year, calcium during the first 30 months, and zinc during the fourth year. Manganese deficiency is suspected after the eighth year. Molybdenum deficiencies were detected in soybeans, particularly when seed produced in acid soils of the Amazon Basin was used, but not when the seed came from more fertile soils of the Peruvian coast.

In the complete treatment, fertilizers and lime were added according to recommendations based on soil analysis. During the second or third year, however, all yields began to decline rapidly. Soil analysis identified two responsible factors: a shorter than expected residual effect of the lime applied, and the triggering of a magnesium deficiency induced by the potassium applications. After these problems were corrected, crop yields stabilized (Fig. 2). Thus, a monitoring of the nutrient dynamics during the period when the soil was undergoing a transi-

Table 4. Changes in topsoil (0 to 15 cm) properties at Yurimaguas after 8 years of continuous cultivation and 20 crops of upland rice, corn, and soybeans with complete fertilization (*26*).

Time	*p*H	Organic matter (%)	Exchangeable, milliequivalents per 100 square centimeters				CEC	Al saturation (%)	Available (parts per million)				
			Al	Ca	Mg	K			P	Zn	Cu	Mn	Fe
Before clearing	4.0	2.13	2.27	0.26	0.15	0.10	2.78	82	5	1.5[*]	0.9[*]	5.3[*]	650[*]
Ninety-four months after clearing	5.7	1.55	0.06	4.98	0.35	0.11	5.51	1	39	3.5	5.2	1.5	389

[*] Thirty months after clearing.

tion from forest to cropland provided the key for establishing continuous cultivation.

Table 3 presents lime and fertilizer recommendations developed during 8 years of research at Yurimaguas. Like all sound fertilizer recommendations, they are site-specific. Nevertheless, they are representative of the level of fertilizer input required for continuous crop production in Ultisols. These fertilizer levels do not differ substantially from those used to grow corn, soybeans, and peanuts in Ultisols of the southeastern United States. On an annual basis, the total amounts of fertilizer required are higher in the Amazon than in the Southeast because three crops are grown instead of one.

Effects of Continuous Cultivation on Soil Properties

It is a common belief that cultivation degrades soils in the humid tropics (*12*, *14*). Our results, however, indicate that soil properties improve with continuous cultivation systems combining intensive management and appropriate fertilization. After 20 consecutive crop harvests at Yurimaguas, the topsoil *p*H increased from a very acid 4.0 before clearing to a favorable level of 5.7 (Table 4). Organic matter content decreased by 27 percent, but most of this loss occurred during the first year. Exchangeable aluminum decreased from very high levels to minimal amounts, exchangeable calcium increased 20-fold (a consequence of lime applications), and exchangeable magnesium doubled. Exchangeable potassium did not increase despite the application of large quantities of potassium fertilizer, suggesting rapid utilization by crops and perhaps losses due to leaching. Effective CEC doubled as a consequence of the *p*H-dependent charge characteristics of the kaolinite clay and iron oxides. Fertilization also increased available phosphorus from below the critical level of 10 parts per million to substantially above it. The same trend occurred with zinc and copper. Available manganese, however, decreased to levels approaching deficiency. Available iron remained considerably above the critical range of 20 to 40 parts per million. On the whole, these changes indicate improvement in the topsoil's chemical properties.

There have been no unfavorable changes in the soil's physical properties thus far because of the protection three well-fertilized crops per year provide against the rains (*26*). Although crop residues are left in the field until the experimental plots are tilled for the next planting, the soil is exposed for up to 30 days before a full crop canopy is reestablished. Occasional runoff losses have been observed, but they have not been of sufficient magnitude to affect yields.

Acid, infertile subsoils of Oxisols and Ultisols frequently act as chemical barriers to root development. Crop roots are unable to enter a subsoil highly saturated with aluminum ions and very low in exchangeable calcium (*28*). This produces shallow root systems, which often result in drought stress during rainless periods (the subsoil may still have plenty of water, but the plants cannot reach it). With time, however, continuous cultivation leads to an alleviation of this problem. We observed significant increases in calcium, magnesium, and effective CEC and a decrease in aluminum saturation in subsoil 15 to 45 centimeters deep (Fig. 3). Fertilization promotes the downward movement of these basic cations, which results in a more favorable environment for root development than before clearing.

Technology Validation in Farmer Fields

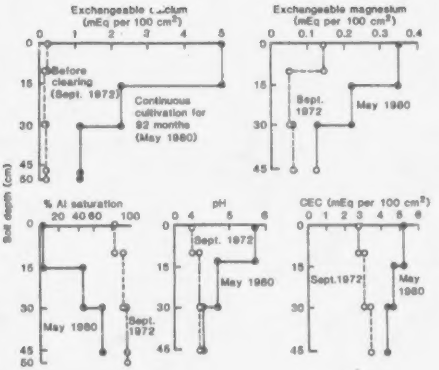
In 1979 a number of demonstration plots were established in shifting cultivators' fields within an 80-kilometer radius of Yurimaguas. Three crop rotations were tested. The complete fertilization schedule (Table 3) was implemented, as adjusted by on-site soil tests (*29*). The first eight farmers averaged 3 tons of rice per hectare, 4.5 tons of corn, 2.6 tons of soybeans, and 1.8 tons of peanuts—yields similar to those obtained at the station. The tests have expanded, and farmers are attracted by the prospect of increasing their yields six- to tenfold (their traditional average is 1 ton per hectare per year) while avoiding the need to clear new land every year.

Economic Implications

The combined results indicate that the continuous production system is economically viable over a wide range of crop and fertilizer prices, capital levels, and labor force compositions (*30*). When it was assumed that only the typical family was available for labor, that the farmer borrowed about U.S.$150 from the agrarian bank, and that fertilizers were bought at world market prices and transported overland from Lima, the annual family income increased four times, from the present average of $750 to about $3000 per 1.5 hectares. Also, for every additional dollar borrowed to buy fertilizer at a marginal cost of $0.18, profits ranged from $1.29 to $4.95 (*30*). Given the favorable response of the Peruvian government to what is now being called the Yurimaguas technology, the local availability of fertilizer and credit has increased and marketing facilities have improved. Several farmers are using the new system, but invariably they have planted larger areas than suggested by the economic analysis. To do so, they obtained outside labor or hand tractors. It is too soon to ascertain the performance of these pioneers.

Current Research Efforts

Continuous cultivation of annual food crops with appropriate fertilization is one of several options for sustained agriculture in the humid tropics. The Tropical Soils Research Program is developing technology for other land uses, with emphasis on intensive crop production in fertile alluvial soils, low-input crop pro-



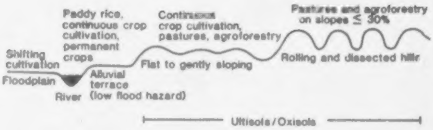

Paddy rice, continuous crop cultivation, permanent crops
Continuous crop cultivation, pastures, agroforestry
Pastures and agroforestry on slopes ≤ 30%
Shifting cultivation
Floodplain
River
Alluvial terrace (low flood hazard)
Flat to gently sloping
Rolling and dissected hills
Ultisols / Oxisols

Fig. 3 (left). Improvement in chemical properties of the subsoil after 7½ years of continuous cultivation of a rotation of rice, corn, and soybeans at Yurimaguas (25). Fig. 4 (right). Rational land-use options for Amazon Basin landscapes. Wherever possible, regions of cultivated Oxisols and Ultisols should be surrounded by forest reserves in a mosaic pattern.

duction systems in Ultisols and Oxisols, and legume-based pastures and agroforestry for sloping Ultisols and Oxisols.

Relatively fertile alluvial soils that are not subject to flooding have a major food production potential. Improved rice varieties and spacing in alluvial soils can result in the doubling of upland rice yields without eliminating shifting cultivation (31). The rotations of three crops per year are producing excellent yields in such soils in field trials. The high *p*H and fertility of these soils eliminate the need for lime and decrease the fertilizer requirements. Research is in progress for developing paddy rice production technology with irrigation water pumped from rivers or wells.

Decreasing the level of fertilization is likely to increase economic returns in the well-drained Ultisols. Ongoing research in this direction includes minimum or zero tillage, utilization of indigenous rock phosphates, and improving the efficiency of fertilization, particularly that of potassium. Selection of varieties of upland rice, soybeans, peanuts, corn, cowpeas, sweet potatoes, and winged beans for tolerance to acid soil stresses is also in progress (32). Promising results are being obtained with rice and cowpeas. The inclusion of such tolerant germ plasm is expected to substantially decrease the lime and phosphorus requirements of continuous cultivation systems.

Organic inputs such as mulch, green manures, and compost have been studied as possible substitutes for chemical fertilizers. Mulching crops with residues from the previous crop or with *Panicum maximum* grass has produced unreliable results in over 20 experiments, with generally detrimental results for upland rice, some positive results for corn, and little effect on soybeans and peanuts (33). These results contrast with the positive results of such practices in Nigeria (34), where the most serious soil problems are physical rather than chemical in nature.

The use of kudzu (*Pueraria phaseoloides*) as a green manure has often resulted in crop yields similar to those following complete fertilization (35). The labor involved in harvesting, transporting, and incorporating kudzu into the soil, however, imposes severe practical limitations. Making compost out of crop residues appears more promising. For the first four consecutive crops, replacing complete fertilization with compost from crop residues resulted in only a 20 percent yield reduction (36). To sustain yields afterwards, it was necessary to apply potassium fertilizer with the compost. The use of this practice is restricted by the high labor requirements of compost making.

Research is also in progress on the use of managed kudzu fallows as an intermediate stage between shifting and continuous cultivation. Kudzu has the ability to establish itself on fairly impoverished soils and to quickly develop a lush green canopy underlain by plenty of nitrogen-fixing root nodules. After 1 or 2 years, the kudzu can be slashed with machetes and burned. Reasonable yields have been obtained by rotating two crops with 1 or 2 years of kudzu fallow (26). During the second rotation potassium is needed to obtain moderate crop yields. It appears that 1 to 2 years of kudzu fallow may have the same restorative effect on previously unfertilized, cultivated cropland as 25 years of forest fallow.

Technology is being developed for pasture production in sloping areas of Ultisols. The system would be based on the use of acid-tolerant grass and legume species selected by CIAT's Tropical Pastures Program. Promising germ plasm has been tested for adaptation in an Ultisol of *p*H 4.0 and 80 percent aluminum saturation with applications of only 50 kilograms of P_2O_5 as simple superphosphate and 50 kilograms of potassium per hectare. Results show that the grasses *Andropogon gayanus*, *Brachiaria humidicola*, and *B. decumbens* and the legumes *Desmodium ovalifolium* and *Pueraria phaseoloides* are well adapted to the soil, climate, and pest and disease constraints of the region (37). The grass and legume pastures are now being tested under grazing.

Many scientists believe that the natural vocation of the Amazon Basin is trees and that ultimately a tree canopy should replace crop or pasture canopies. Research is being initiated to combine crop production systems with promising tree species such as *Gmelina arborea*, oil palm, and pejibaye (*Guilielma gasipaes*). Figure 4 illustrates some of the alternatives. Agricultural land should be integrated with forest reserves in a mosaic pattern to avoid the potentially undesirable effects of large areas of cleared land.

Ecological Implications

Regardless of the many objections voiced against further clearing of the humid tropical forests, land-hungry farmers are migrating to these regions and to large urban centers already present in the Amazon Basin. Increasing demand for food at the national and world levels suggests that this trend will accelerate during the next decades. Our experience and data show that attempts to produce food crops or pastures in acid soils of the humid tropics on a sustained basis without correct technology are [illegible] pastures (32). With technology that is agronomically and economically sound, the situation can change from one that is ecologically damaging to one that will maximize production per unit area on a sustained basis. We believe that the continuous cropping technology can have a positive ecological impact where it is practiced appropriately, because for every hectare that is cleared and put into such production, many hectares of forest may be spared from the shifting cultivator's ax in his search to grow the same amount of food. People do not cut tropical rainforests because they like to, but because they need to grow food or fiber. Intensive cultivation of cleared land is one way to satisfy the food demands with minimum clearing. In fact, we hope that this technology will be interspersed with areas of virgin forests, pastures, and tree plantations in a way similar to the mosaic one now finds in much of southeastern United States, where shifting cultivation was the predominant system only a few decades ago.

Limitations

It would be unwise to assume that continuous cultivation technology is directly applicable to the millions of hectares of Ultisols and Oxisols in the humid tropics. Our work has concentrated on nearly level soils, thereby avoiding the erosion hazard of cultivating sloping lands. Landscape adaptations, including terracing such as is practiced in parts of humid tropical Asia, would be needed for continuous cultivation on sloping lands. Legume-based pasture or agroforestry appears more attractive for sloping lands. Our recommendation is to concentrate on the vast areas of nearly level land. In the Amazon there are 207 million hectares of well-drained Oxisols and Ultisols with slopes of 0 to 8 percent (Table 1).

Although weed, insect, and disease attacks were alleviated in this study by crop rotation, selection of varieties reasonably tolerant to pest attacks, and judicious use of insecticides and herbi- [illegible] likely to increase in the future. Experience in other regions with acid, infertile soils indicates that plant protection becomes a major problem once soil constraints are attenuated (9).

Another limitation is the variability in socioeconomic conditions. The Yurimaguas area, although hardly a privileged region of the Amazon Basin, has an unpaved road and a river which link it with the rest of the country—a rudimentary market system. Present socioeconomic conditions indicate a clear economic feasibility in Yurimaguas. It would be foolish to attempt continuous cultivation in areas with little market accessibility, unattractive cost: price ratios, or restrictive governmental policies.

Finally, the new technology must be tested locally to determine any necessary modifications. Such modifications might involve the use of different crop species, varieties, rotations, and certainly fertilizer rates. A simple but efficient soil fertility evaluation service, consisting of a soil testing laboratory and advisory services (39), is essential to assist farmers as they change to continuous cultivation.

References and Notes

1. *World Food and Nutrition Study* (National Academy of Sciences–National Research Council, Washington, D.C., 1977), vol. 4.
2. *Ecology and Development in the Humid Tropics* (National Academy Press, Washington, D.C., in press).
3. N. Myers, *Conversion of Tropical Moist Forests* (National Academy of Sciences–National Research Council, Washington, D.C., 1980).
4. P. T. Alvim, *Um Modelo Contra os "Mitos" da Amazônia* (Commissão Executiva do Plano da Lavoura Cacaueira, Itabuna, Bahia, Brazil, 1979).
5. *Agriculture Toward the Year 2000* (Food and Agriculture Organization, Rome, 1978).
6. A. Tanco, Jr., *Plenary Address to the Bonn Conference on Agricultural Production* (Rockefeller Foundation, New York, 1980).
7. *Priorities for Alleviating Soil-Related Constraints to Food Production in the Tropics* (International Rice Research Institute, Los Baños, Philippines, 1980).
8. C. E. Kellogg and A. C. Orvedal, *Adv. Agron.* 21, 109 (1969).
9. P. A. Sanchez and J. G. Salinas, *ibid.* 34, 279 (1981).
10. D. Marchetti and A. D. Machado, Eds., *Cerrado: Uso e Manejo* (Editerra, Brasilia, Brazil, 1980).
11. R. J. A. Goodland, *Environ. Conserv.* 7, 9 (1980).
12. H. Sioli, in *Land, People, and Planning in Contemporary Amazonia*, F. Barbira-Scazzochio, Ed. (Cambridge Univ. Press, Cambridge, 1980), pp. 257–268.
13. S. Brown, A. E. Lugo, B. Leigel, *The Role of Tropical Forests in the World Carbon Cycle* (Department of Energy, Washington, D.C., 1980).
14. M. McNeil, *Sci. Am.* 211, 86 (May 1964); J. Setzer, *Rev. Bras. Geogr.* 29, 102 (1967); R. J. A. Goodland and H. S. Irwin, *Amazon Jungle: Green Hell to Red Desert?* (Elsevier, Amsterdam, 1975); I. Friedman, *Science* 197, 7 (1977); G. Irion, *Naturwissenschaften* 65, 515 (1978).
15. C. F. Marbut and C. B. Manifold, *Geogr. Rev.* 16, 414 (1926).
16. Soil Survey Staff, *Soil Taxonomy* (Soil Conservation Service, Department of Agriculture, Washington, D.C., 1975).
17. *Soil Map of the World* (Unesco, Paris, 1971 to 1979), vols. 1 to 10.
18. T. T. Cochrane, J. A. Porras, L. Azevedo, P. G. Jones, L. F. Sanchez, *Explanatory Manual for CIAT's Computerized Land Resource Study of Tropical America* [Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia, 1979].
19. T. T. Cochrane and P. A. Sanchez, in *Amazon Land Use Research* (CIAT, Cali, Colombia, in press).
20. P. A. Sanchez and S. W. Buol, *Science* 188, 598 (1975).
21. H. Klinge, *J. Soil Sci.* 16, 95 (1965); *Amazoniana* 1, 303 (1968); *Acta Amazônica* 1, 69 (1971); *Trop. Ecol.* 16, 18 (1975); N. Stark, *Biotropica* 10, 1 (1978).
22. S. W. Buol, P. A. Sanchez, R. B. Cate, M. A. Granger, in *Soil Management in Tropical America*, E. Bornemisza and A. Alvarado, Eds. (North Carolina State University, Raleigh, 1975), pp. 126–141.
23. P. H. Nye and D. J. Greenland, *Commonw. Agric. Bur. Tech. Commun. 51* (1960).
24. P. T. Alvim, *Interciencia* 3, 243 (1978).
25. D. J. Greenland, *Science* 190, 841 (1975).
26. Detailed data are recorded in the Tropical Soils Program's annual reports (North Carolina State University, Raleigh, 1972, 1973, 1974, 1976, 1978, 1980, and 1982).
27. C. E. Seubert, P. A. Sanchez, C. Valverde, *Trop. Agric. (Trinidad)* 54, 307 (1977); P. A. Sanchez, in *Soils Research in Agroforestry*, H. O. Mongi and P. A. Huxley, Eds. (International Council for Research in Agroforestry, Nairobi, Kenya, 1979), pp. 79–124.
28. E. Gonzalez, E. J. Kamprath, G. C. Naderman, W. V. Soares, *Soil Sci. Soc. Am. J.* 43, 1155 (1979); K. D. Ritchey, M. G. Djalma, E. Lobato, O. Correa, *Agron. J.* 72, 40 (1980).
29. R. Mesía, D. E. Bandy, J. J. Nicholaides, *Agron. Abstr. 1979* (1979), p. 46.
30. D. G. Hernandez and A. J. Coutu, *Agron. Abstr. 1981* (1981), p. 42.
31. P. A. Sanchez and M. A. Nureña, *N.C. Agric. Exp. Stn. Techn. Bull. 210* (1972).
32. M. Piha and J. J. Nicholaides, *Agron. Abstr. 1981*, p. 45 (1981).
33. C. Valverde and D. E. Bandy, in *Amazon Agricultural Land Use* (CIAT, Cali, Colombia, in press).
34. R. Lal, *Int. Inst. Trop. Agric. Monogr. 1* (1975).
35. M. K. Wade, thesis, North Carolina State University, Raleigh (1978).
36. D. E. Bandy and J. J. Nicholaides, *Agron. Abstr. 1979* (1979).
37. M. Ara, P. A. Sanchez, D. E. Bandy, J. M. Toledo, *Agron. Abstr. 1981* (1981), p. 38.
38. J. M. Toledo and E. A. S. Serrão, in *Amazon Agricultural Land Use* (CIAT, Cali, Colombia, in press).
39. For examples of a successful system, see E. Bornemisza and A. Alvarado, Eds., *Soil Management in Tropical America* (North Carolina State University, Raleigh, 1975), pp. 455–532.
40. This is Paper 8240 of the journal series of the North Carolina Agricultural Research Service, Raleigh, in cooperation with the Instituto Nacional de Investigación y Promoción Agraria, Peru. Supported by contract AID/ta-C-1236 and the Soil Management Collaborative Research Support Program of the U.S. Agency for International Development. Work reported here reflects the contributions of J. Alegre, M. A. Ara, J. R. Benites, S. W. Buol, D. K. Cassel, R. B. Cate, A. J. Coutu, D. G. Hernandez, C. E. Lopez, R. Mesía, M. A. Nureña, M. Piha, C. E. Seubert, E. J. Tyler, C. Valverde, J. Van Diepen, and M. K. Wade.

Dr. Richard R. Harwood

THE PRIVATE SECTOR ROLE IN THE DEVELOPMENT AND SPREAD OF RESOURCE-EFFICIENT ALTERNATIVE AGRICULTURAL TECHNOLOGIES

I. The Types of Organizations Involved

Networking Groups - There are several organizations which serve to link U.S. scientists, especially those working in alternative technologies, with third world countries. Appropriate Technology International has a broad mandate covering not only agricultural but energy and other issues as well. This group provides contacts for third world development projects from among U.S. scientists included in their list of resource persons and organizations. ATI does no research on its own. A second networking group whose mandate is specific to food is the League for International Food Education (LIFE) which provides "the link between people with questions and people with answers." Both of these groups have broad contacts in public and private institutions. Both are focused on exchange of information between the U.S. and third world countries.

Non-profit Development Groups

There is a small number of non-profit development organizations having at least a portion of their work devoted to alternative agriculture. Many have direct links to third world agriculture. Examples of such organizations are The New Alchemy Institute, Ecology Action of the Mid Peninsula (in Santa Barbara, CA), The Farallones Institute and the Frank Porter Graham Center.

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Alternative Agriculture Member Organizations

There are several member organizations specific to alternative (organic, biological) agriculture. The International Federation of Organic Agriculture Movements is the largest, serving to network approximately 1000 individuals and organizations on a worldwide scale. This organization publishes quarterly bulletins in the English and German languages containing research summaries and overviews of relevant happenings in organic agriculture. It holds bi-annual international symposia with published proceedings.

The Institute for Biological Husbandry and the Henry Doubleday Foundation are smaller but similar organizations based in England. Both work internationally.

There are numerous alternative agriculture practitioner groups within the U.S. Many are comprised of commercial farmers. Most publish newsletters and hold regular meetings of their members. The Natural Organic Farming Association (NOFA) in New England and Tilth in the Pacific Northwest are the largest. There are many statewide associations of organic growers such as in Michigan, Kansas, Nebraska, Ohio and California.

Private Corporations

Other organizations such as Acres, USA, a publishing company and several private corporations marketing alternative agricultural products such as Wonder Life Corporation and Bio Ag in Michigan serve the educational and research needs of organic farmers. Rodale Press, Inc., is a publishing company with a major commitment to research which falls into this category.

I will not go into detail or provide a comprehensive list of these organizations. In summary, there exists a loosely-knit network of groups in the U.S. and Europe focusing on their common interest, alternative agriculture. For the most part these groups function outside the normal public (and conventional private) agricultural sectors. They have varying linkages with public research institutions and with third world development projects.

II. Research into Alternative Agricultural Systems

I will focus primarily on that work related to organic or "biological" agriculture. While organic agriculture is not the direct focus of this inquiry, its underlying direction is one of minimal use of inputs of any kind. Organic systems are structured for high productivity and efficient use of resources through interaction of the various biological components of the system. The many methodologies included under the general heading of "alternative agriculture" are thus highly relevant to this study.

There are two categories of related research that I will not cover. First of all, there is a good deal of work in public institutions which provides basic technology for low-input systems. Of note would be much of the work on nitrogen fixation by free-living as well as symbiotic organisms. The development of high yielding forage legume species fits in this category. Integrated pest management systems which are more informatic intensive as opposed to chemical-intensive are another example. Much of this work is of prime relevance to your study. A second category of low-input type research is done by agribusiness firms dealing with products for organic systems. These companies research the use of humates, zeolites, microbial products, soil conditioners and non-traditional nutrient sources for use in low-input alternative agricultural systems. Along more conventional lines, the newly introduced microbial feed additives enhance digestibility of animal feeds for more efficient utilization. Many of the soil-applied products are offered for sale in third world countries.

The major problems with their use in the third world, as in the U.S., involves information on their efficacy across environments. Because they are offered by relatively small companies with limited research funds and capability, this information is usually scanty if it is available at all. While many of these products may have benefit, they haven't been well evaluated.

Organic-Related Research

I would like to focus on that alternative work concentrated in the private sector which centers on the organic philosophy. First of all, there are the self-reliance technologies generally grouped under the heading of "gardening." This work is primarily directed toward development of techniques or practices for small-scale food production. It is common to many of the non-profit organizations such as New Alchemy and Ecology Action. Included are such techniques as the French Intensive bed growing system, permaculture systems, composting methods, biogas-crop systems, small scale bioshelters, small scale aquaculture systems and the raising of small animals such as rabbits, quail and others. The work is very much applied. Several organizations include applications of these techniques to the third world. Many publish research reports or user manuals. Their information is in considerable demand by ATI, church groups, the Peace Corps and similar organizations working in the third world. Our own Organic Gardening magazine is the single major source of such information, but is directed almost exclusively toward a U.S. audience. Judging from the many requests that we receive from the third world, there is a need for much more of this type of information. Difficulties in developing such information include its environment-specificity, the lack of clear definition by the developing agencies as to the environments it is suited for, and the extremely diverse nature of the developing groups. While these types of technologies haven't been the focus of major development efforts in the third world, my own experience indicates that they would go a long way toward improving the well-being of the great majority of third world peoples. The social diversity of target audiences as well as the multitude of technologies involved makes the task a formidible one if conducted on a large scale. There are numerous private development agencies working at the individual village level which would profit immensely from such information.

A second and even more widely important area of research is that on commercial scale organic systems. This is the work carried out by several participants in the IFOAM network. The Rodale Research Center is the leader in this area. There are several types of levels of such research that might be discussed.

The first type is the "whole-farm" research comparing organic with conventional farms or that describing in detail the operations of organic farms. The most authoritative overview of this work is provided in the USDA's report on organic farming (1). A more detailed scientific study of 50 midwestern organic farms as compared to their conventional counterparts was done in a Washington University study as widely reported over the past several years by Lockeretz (2). This study concluded that the organic farms had yields ranging from the same to as much as 10% below those of conventional farms. Net incomes were about the same, but energy costs per dollar of crop or livestock produced were 60% lower. There are less extensive but similar studies being done of organic farms in Michigan by Michigan State University, in North Carolina and in Washington State. At the Rodale Research Center, we have been working for a year on a 7-state study starting with 3500 farms and narrowing down to about 100 for detailed survey and farm visits. Dr. Patrick Madden, an economist at Pennsylvania State University and I are collaborating in this work. An extremely intensive 4-year study of an organic beef operation in Pennsylvania is being completed this winter by Dr. Earl Partenheimer of Pennsylvania State University in collaboration with the staff of the Rodale Research Center. These studies give an overview of a small, highly subjective sampling of the 30,000 to 40,000 farms in the U.S. considered to be organic. The results seem to indicate the following:

1. Size of organic farms varies nearly as greatly as for conventional farms. There is indication that average size is about the same as for conventional farms.
2. Organic farms include nearly every type of operation, but are most commonly found among beef, dairy and small grain operations.
3. West Coast operations tend to be non-livestock operations with crop specialization. Central and eastern U.S. operations tend to be livestock-oriented.
4. The systems are more management-intensive.
5. They have significantly less cash input costs.
6. Variable production costs are usually lower, with a higher proportion of variable cost being machinery and labor as compared to conventional farms which have higher input costs for fertilizer and pesticides.
7. Inputs are reduced primarily by structuring interactions within the system:

   A. Crop rotation for reduction in weed control and soilborne insect and disease control costs.

B. Use of leguminous cover crops in and around cash grain crops (cash crops are rarely replaced by a cover crop). Little off-farm nitrogen is thus used by most farmers.

C. Integration of crops and livestock on many farms.

D. Sophisticated integrated pest management programs.

8. Long-term nutrient use efficiency brought about by several (as yet not fully defined) organic practices. Soil test results on many long-term organic farms show above-average nutrient values in spite of a nutrient deficit caused by low inputs. The most outstanding and well-documented case is that reported by Patten (3). An 800-acre dryland wheat farm in the Palouse of Washington State has been farmed organically but with no input of nutrients for 75 years. Crop yields, as well as could be determined, were about equal to those of conventional farms. The soil phosphorus and potassium levels were considerably higher on the organic (Lambert) farm than on the neighboring farm (Figures 1, 2) in spite of regular phosphorus application on the conventional farm. The organic philosophy contains numerous claims for this type of favorable comparison, brought about by differences in long-term vertical nutrient movement within the soil.

There would appear to be obvious benefit from the information coming from these on-farm studies. Their apparent resource use efficiency and their substitution of management inputs for product inputs would seem to have application in a resource-scarce future in the U.S. as well as in the third world. Such systems have implications for environmental protection as well.

There are several limitations to this type of research. The results are descriptive, but it is difficult to separate technology from environmental and management capability variables. Because of this high variability, it is difficult if not impossible to replicate observations. Such work is of interest to economists but of limited attractiveness to crop and animal production scientists. It, therefore, has only limited financial and staff backing.

Another category of organic research involves replicated comparisons of organic and conventional systems. As far as I know there are three locations in the U.S. and one in Europe presently doing this work. A long-term study at the University of Nebraska, one at the University of Maine and two at the Rodale Research Center are in this category. The Rodale studies are not only looking at the comparison between organic and conventional but are following the comparison through the "conversion" from conventional practice to organic and from organic to conventional. It is commonly held by organic practitioners that there is a 3 to 5 year transition period in going from conventional farming to organic in which changes occur in the soil, prompting a drastic reduction in crop yields and then a gradual recovery. The first two years of our conversion experiments confirm a decline in yields which is very much crop-dependent. Corn is the most seriously affected, but small grains including wheat and oats as well as soybeans show far less effect. Manure application helps, but short-term legume sod rotation using clover seems to be the most effective. A range of "organic" products which are claimed to help in the transition are offered by the previously-mentioned agribusiness firms, but their claims are not well verified.

Our results to date indicate that there may be differences in nitrogen form in the soil between the systems. After two years of conversion there are differences in microbial activity as measured by CO_2 evolution. We do not as yet know the significance of these changes. There is strong indication, however, of chemical, physical and biological differences in the soil between the systems. We hope to verify or disprove differences in vertical movement of nutrients in the soil. This work will help to establish the impact of conventional practices on efficiency of use of inputs as compared to alternative systems.

Limitations and difficulties of this work are its long-term nature, the complexities of researching completely different rotations and practices and its high cost. It requires effective interdisciplinary coordination for effective implementation. It will eventually help to clarify many of the issues relative to organic agriculture.

Other areas include research on insect-repellent plants. In searching the organic literature, we have found reference to many plants having such properties. Two, catnip and tansy, have consistently reduced certain insect pest numbers when interplanted in replicated trials by over 60%. Extracts of these plants seem to have similar results. These plants could be of real benefit in the third world countries where crop mixtures are commonly grown.

We have been working for about 5 years with the overseeding of legumes into standing crops of wheat, corn and soybeans. In many environmental zones this practice has a major effect on nitrogen balance in the rotation and on reduction of soil erosion.

We have been working, for about 10 years, with an expenditure of over 2 million dollars on amaranth as a grain crop for semi-arid areas and as a leafy green for hot humid regions. The grain is outstanding in nutritive value. It could prove of value in the sub-Sahelian zone and in smaller but environmentally similar areas.

I have appended a paper given in a special symposium on organic agriculture by the American Society of Agronomy which goes into our research in greater detail (4). The research areas covered in this paper and elaborated on in the ASA paper are quite representative of those common to the organic field.

III. The Relevance to Third World Agriculture

My own experience indicates that the development model common to third world countries presupposes the desire for achieving high energy-flow systems with high use of goods and inputs, the creation of a rural infrastructure to move and support them and the use of credit and banking facilities to make it all possible. The realities of many third world, resource-limiting situations have limited the spread of such high energy-flow technologies to the more resource-plentiful environments. Our development efforts have largely bypassed the many other areas.

My feeling is that there is considerable scope for development within subsistence systems. The small-scale technologies of organic gardeners are found in such situations, but with a few notable exceptions are not well developed. The homestead areas of Indonesia, of the Nepal Himalayas and the private plots of China are comparable in technology to the better U.S. and European models.

In commercial agriculture only the Chinese model compares favorably to the highly developed U.S. and European commercial farms in productivity. Unfortunately, the Chinese are looking toward conventional avenues for their development directions. As an example of the extremes in thinking which the high energy-flow model leads to, I would point to an example from Nepal. In April of 1982 I was working with a USAID development project in western Nepal. The project had introduced new wheat varieties whose yield could be doubled in many fields by the addition of nitrogen. Urea fertilizer was being imported into Calcutta through a European assistance program, trucked at high expense into the foothills and then portered 3 days over mountain trails into the hills. Neither the Nepal nor the AID mandate was sufficiently broad to look at biological nitrogen production which could be accomplished most readily using woody leguminous species. Nepali scientists were astonished to hear of the Delaware acreage of corn that is self-sufficient in nitrogen through overseeding of vetch. They saw this as a "retreat to methods of the 1930's." Perhaps the greatest contribution that alternative technologies could make would be to broaden the options for third world development. I personally feel that as a development scientist I now have a much more broad array of tools to work with after exposure to alternative methods as I consult third world projects.

The transfer of information back to the U.S. as a benefit to American farmers is more difficult. For several years I worked in Asia with rice-based farming systems and have seen them in use in China as a member of a study team of the Committee on Scholarly Exchange with the People's Republic. Most of the traditional technologies do not transfer easily to the U.S. Little work has been done on them to come to an understanding of basic principle. Those principles would be a most valuable resource to us but their understanding is complex.

The research and understanding of alternative systems in the U.S. has similar difficulties and faces similar complexities. As we approach their study with greater determination, we are beginning to document the contributions that they can make. I see a very clear symbiosis developing between our efforts and those of development agencies working in the most disadvantaged areas of the third world.

In short, we are really addressing the subject of a new paradigm; one which indicates a need for quite radical changes in development thinking. We are working with technologies which are regenerative; which add to our resource base rather than detract from it as production is increased. There is a strong need for a continued and strengthened congressional mandate for at least token levels of research into the many alternative strategies.

LITERATURE CITED

1. Study Team on Organic Farming. 1980. Report and recommendations on organic farming. United States Department of Agriculture. 620-220-3641. 94 pp.

2. Lockeretz, William, G. Shearer and D. H. Kohl. 1981. Organic farming in the corn belt. Science 211:540-547.

3. Patten, Andrea. 1982. Comparison of nitrogen and phosphorus flows on an organic and conventional farm. Master of Science Thesis, Washington State University. 108 pp.

4. Harwood, Richard. 1983. Organic farming research at the Rodale Research Center in: Current Technology and its Role in a Sustainable Agriculture. American Society of Agronomy (in press).

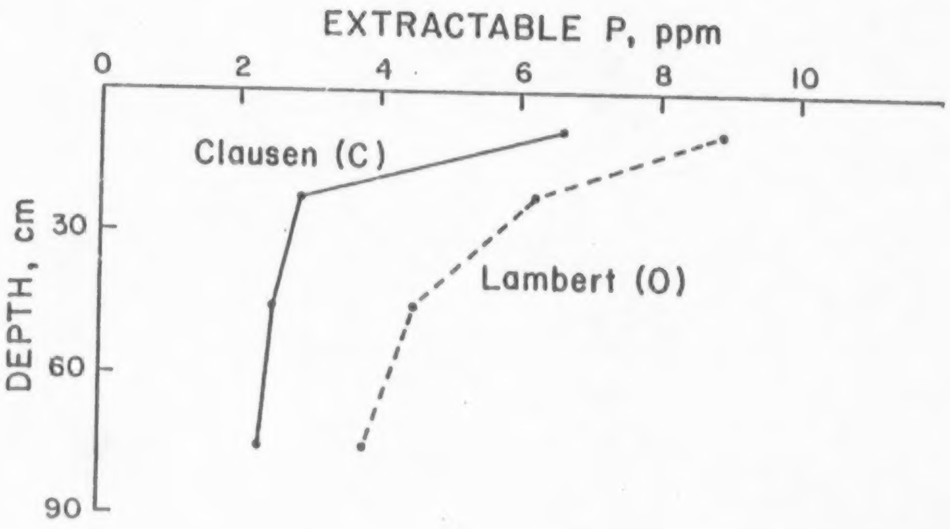

Figure 1. Average concentrations of extractable P with depth in the Lambert (Organic) and Clausen (Conventional) summer fallow and winter wheat plot soils from Fall, 1980 and Spring, 1981 sampling dates.

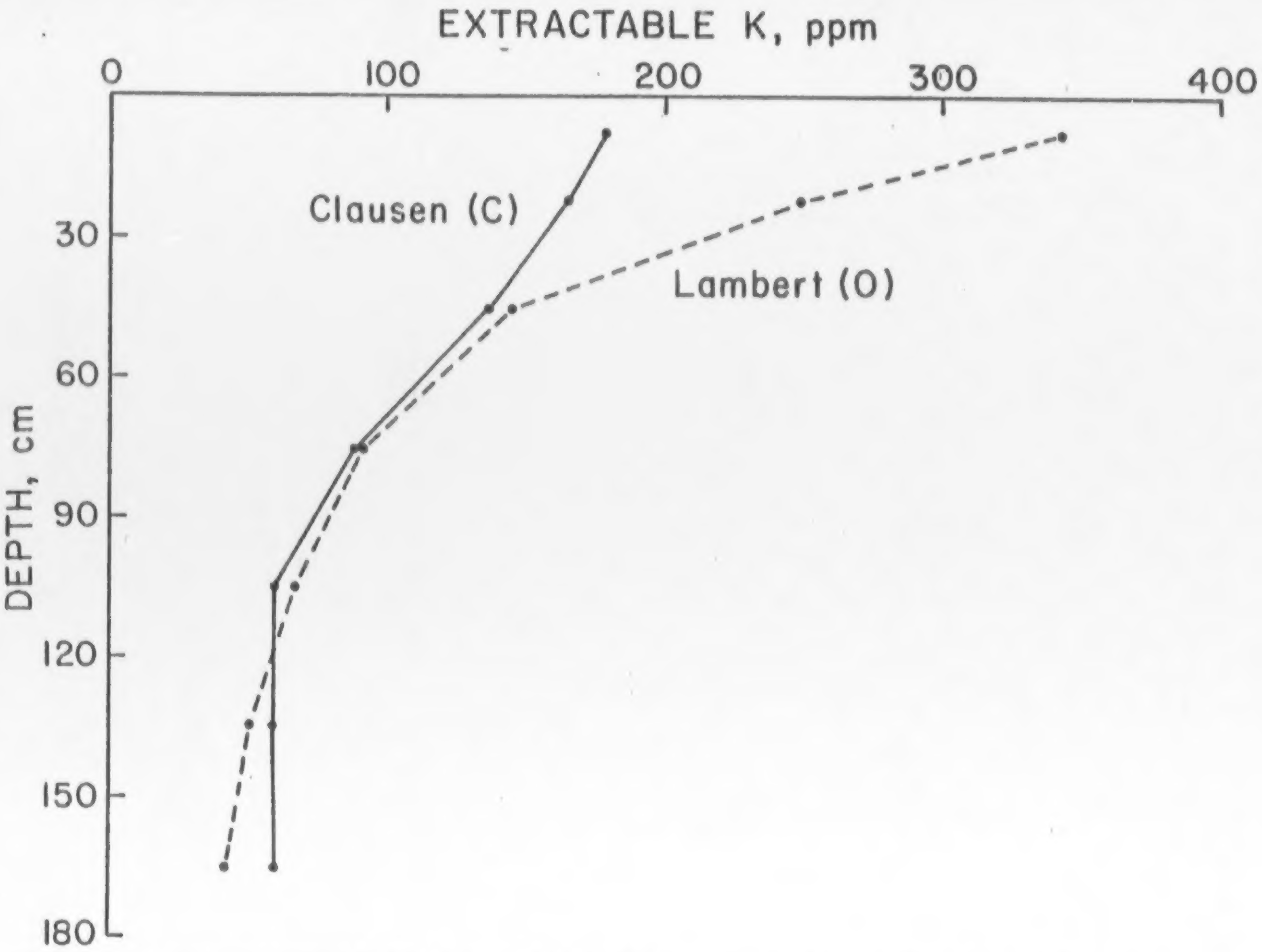

Figure 2. Average concentrations of extractable K with depth in the Lambert (Organic) and Clausen (conventional) summer fallow plot soil, Fall 1980.